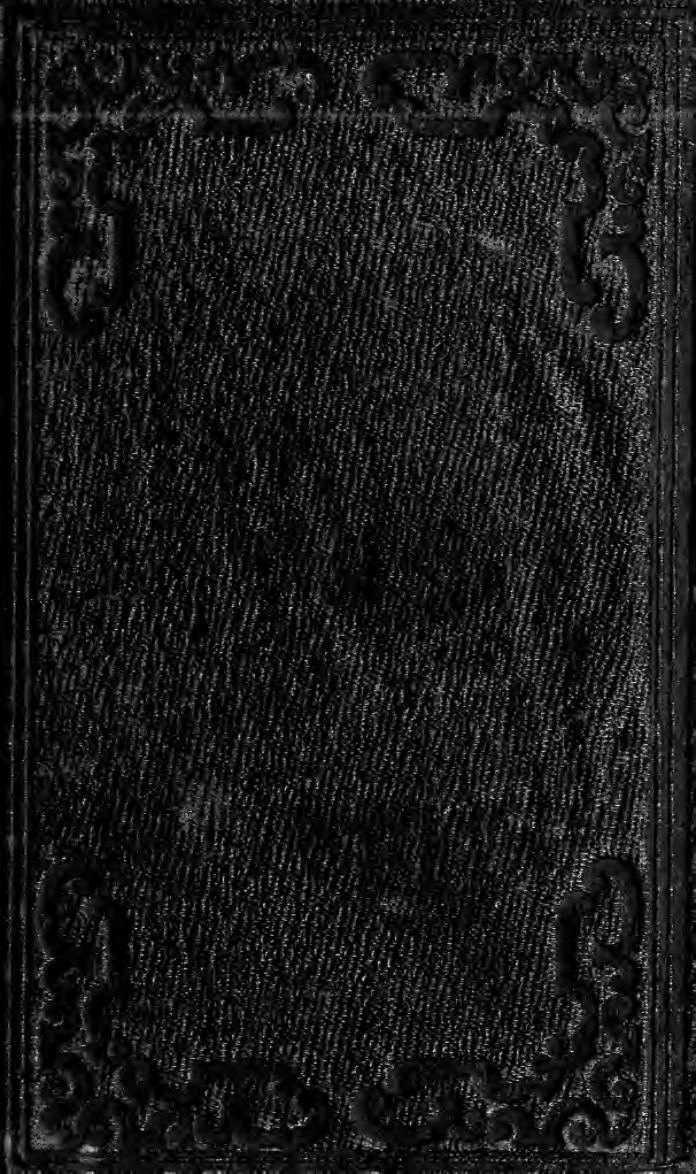

LECTURES

ON

ELECTRICITY AND GALVANISM.

LECTURES

ON

ELECTRICITY AND GALVANISM,

IN THEIR

PHYSIOLOGICAL AND THERAPEUTICAL RELATIONS,

DELIVERED AT THE

ROYAL COLLEGE OF PHYSICIANS,

REVISED AND EXTENDED.

BY

GOLDING BIRD, A.M. M.D. F.R.S. F.L.S.

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TO

J. A. PARIS, M.D., CANTAB., F.R.S.

PRESIDENT OF THE ROYAL COLLEGE OF PHYSICIANS,
ETC., ETC.

MY DEAR SIR,—

To no one could these Lectures be so appropriately inscribed, as yourself. Indebted to you for the high honor of being called upon to address the College,—aided by you in the selection of the subjects of my Lectures,—stimulated by your example in the cultivation of those branches of Physical Science which are related to Medicine,—I owe you a debt of gratitude, which I can thus but feebly and imperfectly repay.

Ever, my dear Sir,

Sincerely and respectfully yours,

GOLDING BIRD.

19 Myddelton Square, Oct. 1, 1849.

PREFACE.

I FEEL it necessary to explain the reasons which have induced me to publish these Lectures in a separate form. In the spring of 1847 I was honored by being appointed one of the Lecturers at the Royal College of Physicians, and chose for my subject Electricity and Galvanism in relation to Physiology and Therapeutics. These Lectures were fully reported in the London Medical Gazette. Since their appearance in the pages of that journal I have been repeatedly urged to publish them as a distinct work, but could never bring myself to regard them of sufficient importance for that purpose. A short time since, however, I was applied to on the same subject by the excellent publishers of the Gazette, who informed me that there had been a considerable

demand for the numbers of the journal in which these Lectures had appeared.

I have been thus encouraged to carefully revise and somewhat extend them, and have added some fresh illustrations, so that I venture to entertain a hope that this little volume may not be unworthy of perusal nor destitute of utility.

Myddelton Square, Oct. 1, 1849.

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LECTURES

ON

ELECTRICITY AND GALVANISM.

LECTURE I.

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MR. PRESIDENT,

More than twenty-three centuries have passed away, since the great father of physic, the "divine old man" of Cos, felt the necessity for the adoption of some conventional term by which he could express the influence under which the different

phenomena, as well of the microcosm of the world at large as of the microcosm of man himself, were developed. We are indebted to his ingenuity for the invention of the hypothesis of a principle which is supposed to influence all the manifestations of creative power observed in the universe. To this he applied the name of φυσις, viz., "nature." Hippocrates, however, invested his φυσις with a kind of intelligence, under which it was supposed to exert a tendency to promote all actions which were beneficial, and redress those which were injurious, to the well-being of man. He, indeed, seems to have regarded it as a kind of tutelary deity; in which dark notion he appears to have been followed by others, on whom a light had beamed which had not reached the distant ages of the Coan sage, and thus leaves them without an excuse for the adoption of such an opinion. We indeed know that

> "Nature is but the name for an effect,
> Whose cause is God!"

and in this light we profess to be investigators into its laws and phenomena. The different sections into which such investigations have been divided, have received the name of physical sciences, or sciences of nature. Of these, the departments devoted to an investigation of the structure and laws of the animal frame, in health and

disease, become the especial object of pursuit of the practitioner of the healing art. If, however, his information be limited to such portions of knowledge exclusively, it will indeed be scanty. He can never be expected to extend the domains of the art he professes, or hope to add fresh appliances to the science of healing.

"Medicina est ars conjecturalis" was the remark uttered some eighteen centuries ago, and such must ever be the case so long as the practitioner of medicine limits himself to his own exclusive pursuits. The light such a man can hope to throw upon any of the phenomena of life, will be often just sufficient to render his darkness visible. But he who, whilst devoting his attention chiefly to the art he professes, at the same time reflects upon it all the light he can derive from the collateral sciences, will often succeed in throwing upon it a beam which illuminates the phenomena he is studying to an extent previously unhoped for. Witness the influence of chemistry and general physics in unravelling the intricate web of many of the vital functions. There have, in all ages, existed men of narrow minds, who have heaped their ridicule upon those who have possessed the advantages to which I have just alluded, as if medicine were the only science in which the element of excellence must consist in a profound ignorance of all other subjects. This mise-

rable delusion is still not without its influence, but no better apology can be offered for the cultivation of the physical sciences than was made by the elegant Celsus:—"Quæ quidem studia, quamvis non faciunt medicum aptiorem tamen medicinæ faciunt." If these views should influence the practitioners of medicine in all nations, how much more ought they to throw a weight of responsibility on those of England. In all other of the European nations, the appellation applied to the professor of our art has always some reference to his individual occupation. Whilst ἰατρος, medicus, medicin, arzt, or their inflections, constitute his title in the Greek, Latin, French, and German tongues respectively, it is in our language alone that he is dignified by the title of *physician*, thus arrogating to himself a title derived from the φυσις of Hippocrates, and which it ought to be his greatest honor to deserve. It must ever be the high and deserved boast of this college, that it first sanctioned the application of the then heterodox and infant science of chemistry to medicine. Its illustrious founder, the great Linacre, was the first physician who, in spite of the then degraded and despised condition of the votaries of chemistry, dared to lend the weight of his high authority and illustrious name to the support of their dogmata, and by effecting an amicable union between the chemists and Galenists,

laid the foundation for most, if not all, the improvements which the art of medicine has undergone since the era of our first president.

I am sure that all whom I have the honor of addressing will concede to me the importance of the physician frequently making excursions into the domain of the physical sciences, and culling from it whatever blossoms he thinks likely to bear fruit in his own peculiar department. That he may often find his cherished sucklings abortive is *probable;* but that he will as often thus graft a vigorous shoot on the venerable trunk of medicine is *certain.*

I have, Sir, ventured to make these remarks as in some sense apologetic for the subject-matter of these lectures, which, at your own wish, are no longer to be limited to the mere details of the materia medica, but are permitted to be devoted to a consideration of some of the applications of physics to medicine. I could only wish that I were more fitted for this honorable task, and would beg to deprecate your patience should I fail in performing this duty properly; for if, used as I am to the duties of the lecture room, I find it impossible to enter the theatre of Guy's Hospital, without a deep sense of my responsibility, how much more must be that feeling enhanced when I find myself addressing the fellows and licentiates of this College, many of whom may

truly be said to be the conscript fathers of my profession, and to whose example and guidance I have long looked up with feelings akin to awe and veneration!

Few subjects have more frequently, or with greater interest from time to time, attracted the notice of the physician than the nature and applications of electricity, and its modifications to medicine and physiology. Too frequently, however, has the importance of this wonderful and ever-present agent been overlooked, and its application to medicine left to the empiric. Recent researches have invested this matter with the deepest interest, both to the physiologist, the chemist, and the man of general science; more particularly when, from late investigations, it appears that we are constantly generating this agent, and that *quoad* the supply of electric matter, man far exceeds the torpedo or the electric eel, and is only prevented from emitting a benumbing shock whenever he extends his hand to greet his neighbor, from the absence of special organs for increasing its tension. I therefore purpose, as the subject of these lectures for the present session, to draw the attention of the College to the part played by electricity in a physiological as well as therapeutical point of view, and hope to show that the functions this agent fulfils in health, and

its applications in disease, are of far greater importance than have been hitherto considered.

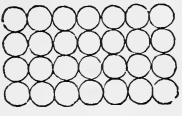
More than 2000 years have elapsed since Thales discovered that pieces of amber, when rubbed, attracted light bodies, and explained the phenomena he observed by supposing that the amber possessed a soul, was endowed with animation, and was nourished by the attracted bodies. Nothing further was added to the observations of the Milesian philosopher until the 13th century, the knowledge of electricity remaining for 1500 years in the same state as among the Indian children on the banks of the Orinoko at the present day, who, according to Humboldt, amuse themselves with exciting by friction the dry and polished seeds of rushes, and attracting filaments of cotton with them. About the time alluded to, a celebrated physician, Gilbert, of Colchester, a contemporary, according to Dr. Friend, of our first Edward, in his essay "de Magnete," recorded several phenomena connected with electrical excitation, and gave to them the title of electricity—a term derived from the Greek word ἤλεκτρον. Notwithstanding the very considerable developments which the science of electricity received, it was not until the beginning of the present century that anything of real value was done towards elucidating its connexion with physiology.

Few things are more interesting and instructive

than to trace the birth and progress of an infant science,—to watch the labor-pangs by which it struggles into existence against the obstacles opposed to it by ignorance, prejudice, and those influences which the illustrious father of the inductive philosophy, the great Lord Bacon, so happily denominated idols, inasmuch as men are too apt, in this blind fealty to the *idola specus, theatri et fori*, to shut their eyes to the first bursts of truth; nor is it until the light of a discovery blazes out with sufficient brilliancy to dispel the mists and fogs of error and preconceived opinions, that much is done towards giving it its proper position in the circle of the sciences. With all such difficulties had the infant science of galvanic or physiologic electricity to contend with; and, had time permitted, it would have afforded me no small pleasure to have pointed out its course from its discovery to the present time. I must now however, content myself with the briefest glance at its history.

Philosophers have almost universally adopted the opinion of matter being constituted by the aggregation of atoms possessing a spherical figure. No one can cast a glance upon a diagram representing a series of spheres without at once perceiving that such bodies cannot touch each other except at

Fig. 1.



certain parts of their peripheries, and consequently the existence of interspaces is obvious; and few subjects in the range of physical science have attracted more attention than the question of the condition of these interspaces, whether they were merely empty voids, or full of some form of matter —whether, in a word, they were *vacua* or *plena*. They have now long been considered to be filled with a light ethereal form of matter, identical, it is presumed, with that which extends beyond the confines of our atmosphere into infinite space, constituting that great ocean of scarcely ponderable medium in which the great orbs of our system roll on in their respective paths. The existence of such a medium is now beyond all doubt or question, from the evidence of its retarding influence upon some of those light cometary satellites, some, probably, scarcely denser than mere whisps of vapor, which occasionally visit the neighborhood of the earth, and which, from their levity, become excellent tests of the influence of a retarding medium. Sir Isaac Newton attempted to calculate the density of this ether, and found that it must be at least 700,000 time less heavy than the air we breathe. Compared to it, therefore, our atmosphere would be far denser than is the solid mass of a granite rock in comparison with air. We know that gaseous bodies, when thrown into a vibratory motion give

rise to certain curious phenomena, very different from those observed when in a state of rest. When such vibrations are performed with a certain regularity and rapidity, they give rise to musical sounds or tones. In like manner, when the interstitial ether is made to assume analogous movements, a new set of phenomena are displayed, differing in their character according to the amplitude and rapidity of their undulations. Thus, when the particles of ether undulate with a rapidity not exceeding 458 millions of millions in a second of time, we have the well-known phenomenon of heat or caloric evolved; when the undulations are increased, so as to range from this number to 727 millions of millions, the various tints of light become developed in addition to heat; whilst, if the vibrations exceed this number, little heat and scarcely any light is to be detected, but they are replaced by the actinic or tithonic phenomena, under whose influence the magic results of the daguerréotype and photography are produced.

Whether electricity is distinct from this ether, or whether the phenomena it produces when it is in what is called a free state, and which are regarded as characteristic of its presence, depend upon ether assuming vibratory movements differing in amplitude and velocity from those producing light, heat, and photographic effects, is yet un-

known. That there is a remarkable connexion between light, heat, and electricity, is, to say the least, quite certain; for one can never be excited without calling into existence one or both the others. The *conventional* theory now generally adopted is, that electricity is a compound imponderable form of matter composed of two elements, denominated the positive and negative electric fluids, which, when separated, produce analogous phenomena, but, when united, neutralize each other so effectually that the existence of the neutral fluid can never be detected, save by separating its component elements. Whilst heat and light are readily detected when set free, by their well-recognised effects, we have, in dealing with the subtle agent whose properties we are now investigating, to use a new series of tests. These are either founded on the law that bodies similarly electrified repel each other, or on the development of the phenomena of light and heat. Nothing is easier than to demonstrate the existence of electricity in ponderable matter, for it can scarcely be submitted to any mechanical, chemical, or thermal influence without decomposing the combined electric fluids.

On the table is an electroscope (Fig. 2*) containing two slips of leaf-gold, hanging parallel to each

Fig. 2. Gold-leaf electroscope, consisting of two slips of gold

other and suspended from a brass cap. Now in common with all bodies, these pieces of gold contain electricity, and yet its presence is not apparent, in consequence of its being in a neutral or combined state; the negative and positive fluids exciting in combination, and neutralizing each other as completely as the sulphuric acid and the magnesia in Epsom Salts. But if we decompose this compound, and set free the electric fluids, the two pieces of gold-leaf will at once render this apparent by exhibiting the phenomena of mutual repulsion. To exhibit this I will now abruptly draw the corner of my silk handkerchief over the cap of the gold-leaf electroscope before me, and thus in an instant shall decompose its neutral electricity, wiping away (as it were) the positive fluid, and leaving the gold leaves negatively electrified, which thus diverge to the extent of an inch or two. On touching the cap with my finger, I give back the positive fluid in sufficient quantity to neutralize the negative electricity of the gold leaves, equilibrium is restored, and they again become quiescent.

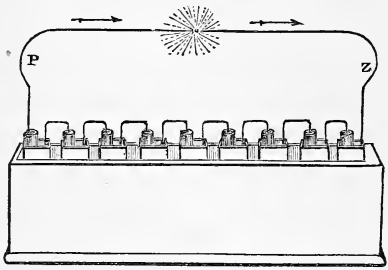
Fig. 2.

To show the influence of chemical action in dis-

leaf suspended within a glass jar from a wire passing through a glass tube, by which their complete insulation is effected.

turbing the normal electric equilibrium, I have here a few glass vessels in which a little nitric acid is undergoing decomposition. The result is, that the electricity of the decomposing atoms is resolved into its two elements, the negative fluid being impelled towards my right hand, and the positive towards my left; and, if the two ends of the series of platinum and zinc plates are connected by these wires, the separated elements unite, and equilibrium is restored (Fig. 3*).

Fig. 3.



With these separated fluids I can produce remarkable effects, depending upon the energy with which their union occurs. I now allow their union to be effected by means of this piece of platinum wire, which becomes brilliantly ignited, from the violence of the neutralization or discharge of the

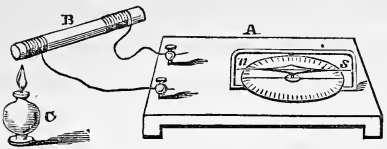
* Fig. 3. Voltaic battery consisting of a series of Grove's cells. The positive current passes from the wire P, connected with the first platinum plate to the wire Z, connected to the last zinc plate, in the direction of the arrows.

two fluids, being sufficient to set in active vibration the interstitial ethereal elements of the platinum, and thus produce the phenomena of heat and light you are now witnessing. I now allow the discharge or union to take place between these fragments of carbon; the intense evolution of light well attests the violence with which the ether is made to vibrate. Now I will compel the two elements to traverse this water before they unite: so powerful is the influence of these wondrous agents, that chemical affinity is annihilated, the water is resolved into its elements, and torrents of oxygen and hydrogen are evolved. Lastly, I have before me two bars of iron surrounded by wire; these are at present merely inert metal, possessing nothing peculiar save in figure. Let us now compel the two fluids to traverse the wire round these bars before they unite. In an instant the bars assume new properties, becoming magnets of enormous power, rapidly and violently attracting the iron ball suspended over them, and seizing, with almost uncontrollable power, the bar of iron I now present to them.

I said that change of temperature is sufficient to disturb the electric equilibrium of bodies. This is invariably true, and a single illustration will, I hope, be regarded as sufficient.

On the table before me is a large magnetic needle suspended on a pivot; some coils of insu-

Fig. 4.



lated copper wire pass above and below the bar, the apparatus being, indeed, the well-known galvanometer (Fig. 4*). Here is a bar of the metal bismuth; and I will twist the terminations of the wire coil round the ends of the bar. The needle remains at rest; no disturbance of electricity occurs. But observe what occurs the instant the flame of a spirit-lamp comes in contact with one end of the bismuth. The magnetic needle, large and heavy as it is, begins to move, and soon traverses an arc of thirty degrees. By the propagation of the calorific vibrations through the bismuth, its electric equilibrium is disturbed, and a current of the positive and negative fluids traverses the wire coil, and produce their well-known effects upon the magnet.

I trust I have not trespassed too long upon your patience in thus bringing before you facts with

* Fig. 4. A, a galvanometer furnished with a coil of thirty folds of thick insulated copper wire, between which is suspended the magnetic needle, *n s*. The bar of bismuth is connected, by copper wire twisted round its two extremities, with the screws of the galvanometer. Heat is applied to one end of the bar by the spirit-lamp, C.

which I am sure all present are familiar. I felt, however, that your time might not be uselessly spent in thus recalling to mind the well-recognised effects of electricity, before passing to its more occult phenomena.

All are ready to admit the presence of electricity in inanimate matter, and, perhaps, to extend it to those animals which are endowed with the mysterious property of benumbing the hand which grasps them; still, all may not be so willing to accord these attributes to man, and to regard him as endowed with a large accumulation of electric fluid.

But nothing is easier than to elicit ample evidence of this truth; and I can readily produce the phenomena of divergence by my own electricity. For this purpose I will stand upon a stool with glass non-conducting legs, and thus, in an electrical sense, am no longer an inhabitant of earth, being insulated from its electricity. Placing a finger of one hand in contact with the cap of the electrometer before me, I with the other will briskly draw a non-conducting comb of tortoise-shell through my hair, the comb being connected with the earth by a wire. Immediately the gold leaves diverge; indeed, I have evolved so much electricity, that one of the leaves has become torn by the violence of its divergence from its companion.

In inanimate nature, we find electricity playing a part so important, that it could scarcely be dispensed with. Many of the most important of the chemical phenomena of the universe would disappear in its absence. *Little* of the intensity of chemical affinity, as it is termed—*few* of the marvellous phenomena so profusely scattered for our inspection and use in the great mineral districts of this and other countries would be developed, were it not for the presiding influence of the wonderful thing we call electricity. There can, indeed, be little doubt of its being one of the most energetic and most generally diffused means employed by the All-wise Creator for the production of most of the phenomena of the material world.

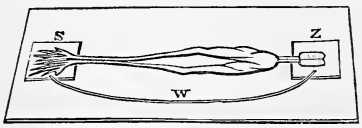
If, then, this agent exists so freely diffused in the animal, can we doubt its having some important function to perform? In the torpedo and silurus its influence is obvious, in furnishing them with powerful weapons of defence and attack; but where its presence is not so evident—where it does not arrest our attention by endowing the animal with a power which enables it to simulate the effects of the lightning-flash—can it exist without fulfilling some important purpose? *Natura nihil agat frustra* is a universally-admitted axiom; nor must we presume otherwise, even when the subject we are

investigating appears less endowed with useful applications.

Professor Galvani, of Bologna, in 1791, published a commentary "De Viribus Electricitatis in Motu Musculari," and announced those facts which laid the foundation of that science which bears his name. He then stated that a particular form of electricity, denominated by him *animal electricity*, existed in animals; and he believed he merely excited and rendered sensible this electricity by coating a nerve and muscle with metals, but did not regard the latter as the real source of the electricity.

This celebrated experiment is well known, I am sure, to all present, but is one of really so marvellous and remarkable a character that, repeat it as often as we may, it can never be looked at without a feeling of wonder and delight. I will take the legs of a frog, denuded of their skin, and attached by the lumbar nerves to a portion of the spine (Fig. 5*).

Fig. 5.



* Fig. 5. The denuded legs of a frog, connected by the lumbar nerves to a portion of the spine. The nerves rest on the plate of zinc, Z; the toes on the plate of silver, S: the two plates are placed in communication by the curved wire, W.

Allowing them to rest on a glass plate, I will place a piece of zinc in contact with the nerves, and allow the feet to rest on a thin slip of silver. They are now at rest, and appear, as they indeed are, dead and powerless. But there exists a power I can call into action which will endow these dead limbs with an apparent life. The only spell required to evoke this power is this piece of wire, with one end of which I will touch the zinc, and with the other the silver. Instantly the legs violently contract, and kick away the silver plate.

It has been lately stated by Professor Matteucci, that this curious observation was not original with Galvani, but was made some time before by the celebrated Swammerdam; and the experiment was exhibited by him in the presence of the Grand Duke of Tuscany.

Shortly after the announcement of this discovery, Professor Volta, of Pavia, in repeating this and other analogous experiments, arrived at a different conclusion; and he showed that the electricity was really excited by the metals, and the contraction of the muscles of the frog was only an index of its existence. Although these and other discoveries of that great man obscured for a time the views and researches of the illustrious Galvani, attention was again drawn to them by the experiments of his talented nephew, Professor Aldini, of Bologna. He was inspired with so

much zeal in the defence of his uncle's theory, that he travelled through France and England for the purpose of demonstrating the truth of his views; and in the presence of the medical officers and pupils of Guy's Hospital, he, in the year 1803, supported and defended a series of propositions so satisfactory and conclusive, that he was presented by his auditors with a gold medal commemorative of his labors. On leaving England, these propositions, and the arguments in support of them, were published in a quarto volume, which seems to have attracted but little notice either here or on the continent of Europe. Scarcely any mention is made of Aldini by more modern writers; and not many weeks ago I removed the volume from the library of the Royal Medical and Chirurgical Society with its leaves uncut.

Professor Aldini's propositions and conclusions are so important, and of such high interest, that I shall now briefly refer to some of them, as they demonstrate to my mind, in a most satisfactory manner, the existence of free electricity in animals, and, as will appear to all conversant with this branch of physiology, most remarkably anticipate the late researches of his countryman, Prof. Matteucci.

Prop. 1.—"Muscular contractions are excited by the development of a fluid in the animal machine, which is conducted from the nerves to the

muscles without the concurrence or action of metals."

Exp. A.—In proof of this statement, Aldini procured the head of a recently-killed ox. With the one hand he held the denuded legs of a frog, so that the portion of the spine still connected with its lumbar nerves touched the tip of the tongue, which had been previously drawn out of the mouth of the ox (Fig. 6). The circuit was completed by grasp-

Fig. 6.

ing with the other hand, well moistened with salt and water, one of the ears. The frog's legs instantly contracted; the contractions ceasing the instant the circuit was broken by removing the hand from the ear.

The intensity of these contractions was much increased by combining two or three heads so as to

form a sort of battery, just as Matteucci, forty years afterwards, found to be the case with his pigeon and rabbit battery.

Exp. B.—Aldini, having soaked one of his hands in salt and water, held a frog's leg by its toe, and, allowing the ischiatic nerves to be pendulous, he brought them in contact with the tip of his tongue. Contractions instantly ensued from a current of electricity traversing the frog's leg in its route from the external or cutaneous to the internal or mucous covering of the body. By this very interesting experiment Aldini demonstrated the existence of the musculo-cutaneous current, and completely anticipated its rediscovery by Donnè some five-and-thirty years after.

Aldini, in connexion with this experiment, declares that the pendulous nervous filaments were distinctly attracted by the tongue; and to this marvellous and hitherto uncorroborated statement calls to witness the then physicians and professors of Guy's and St. Thomas's Hospitals, as well as two well-known fellows of this College, Sir Christopher Pegge and Dr. Bancroft, to whom he states he showed this experiment at Oxford.

Exp. C.—The proper electricity of the frog was found by Aldini to be competent to the production of contractions. For this purpose he prepared the lower extremities of a vigorous frog,

and, by bending up the leg, brought the muscles of the thigh in contact with the lumbar nerves

Fig. 7.

(Fig. 7): contractions immediately ensued. This experiment is now a familiar one, and has been repeated and modified lately by Müller and others.

Exp. D.—A ligature was loosely placed round the middle of the crural nerves, and one of the nerves applied to a corresponding muscle: contractions ensued; but, on tightening the ligature, convulsions ceased.

This statement is very important, as upon its accuracy or error depends what has been regarded as one of the tests of the identity or diversity of the electric and nervous agencies. It was repeated soon after Aldini's announcement of the fact by an Italian physician of celebrity, Signor Valli, who commenced his researches indeed in 1792, only a year after the publication of Galvani's discovery, and he found if the ligature were applied *near the muscle it did not allow the contraction to occur, but if nearer the spine it did not prevent it.* This was afterwards corroborated by Humboldt. I may here remark that it has been

since found by Prof. Matteucci, that, if care be taken to insulate the nerve, a ligature does arrest the contraction, as well as the passage of a very weak artificial electrical current.

Little occurred during the subsequent thirty-five years to modify these conclusions or add to their interest, repeated and extended by numerous observers, especially by Humboldt and more lately by Müller. They were almost lost in the blaze of novelty surrounding the vast discoveries made on the constitution of inorganic matter by the magic pile of Volta, an instrument which, in the hands of our late talented countryman, Sir Humphry Davy, resolved many bodies previously considered simple into their constituent elements, and quite changed the face of chemistry; and still more recently, directed by the gifted genius and vast attainments of a Faraday, has led to the discovery of new sciences, and of properties of matter before undreamed of; indeed, has promised to lay open to us the secrets of the working of the invisible agents presiding over the ultimate constitution of material masses.

I cannot in this place pass over in silence the neuro-electric theory of Galvani. He assumed that all animals are endowed with an inherent electricity appropriate to their economy, which electricity, secreted by the brain, resides especially in the nerves, by which it is communicated to

every part of the body. The principal reservoirs of this electricity he considered to be the fibres of muscles, each of which he regarded to have two sides in opposite electric conditions. He believed that when a muscle was willed to move, the nerves, aided by the brain, drew from the interior of the muscles some electricity; discharging it upon their surface, they thus contracted and produced the required change of position. This theory was adopted and defended by Professor Aldini.

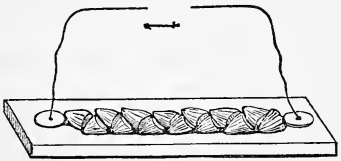
Valli, to whose experiments I have before referred believed the neuro-electric fluid to be secreted by the capillary arteries supplying the nerves, by which it became conveyed to the muscles, which he believed to be always in an electric condition, the interior being negative, the exterior positive. He also noticed the curious fact, that in experiments on frogs, the nerves lose their irritability to the stimulus of electricity at their origin first, retaining it longest at their extremities; and on this hazarded an opinion that probably the distal extremities are really the origin of these structures. Both these statements are of deep interest; the former from its bearing on the late researches of Prof. Matteucci, the latter from its curious connexion with some views of Dr. M. Hall, regarding the centripetal origin of incident nerves.

It may now be asked, what proof do we possess that the action on the muscular fibre of a frog's leg, to which I have alluded, is really produced by electric currents? It is true that this is generally taken for granted, but still it is important to review our proofs. One great evidence in favor of this opinion is at once found in the fact, that contractions produced in frogs can only be excited when connexion is made between a nerve and muscle by a conductor of electricity, all other bodies interfering with the production of this phenomena. The only thing amounting to positive proof before the researches of Matteucci is an experiment of Valli, in which he formed a sort of battery of fourteen prepared frogs, and, by the electricity thus accumulated, succeeded in producing the phenomena of divergence in a delicate electrometer. It is to be regretted that no accurate account of this experiment has been left on record; for, if true, it must be regarded as most satisfactory in proving the identity of the electricity of the frog with that obtained from other sources.

The recent researches of Prof. Matteucci, of Pisa, have, however, completely set this matter at rest. He has incontestably proved that currents of electricity are always circulating in the animal frame, and not limited merely to cold-blooded reptiles, but are common to fishes, birds, and mammalia. From the researches of this phi-

losopher, it appears that a current of positive electricity is always circulating from the interior to the exterior of a muscle; and that although the quantity developed is exceedingly small, yet that, by arranging a series of muscles having their exterior and interior surfaces alternately connected, he developed sufficient electricity to produce energetic effects (Fig. 8). By thus arranging a

Fig. 8.

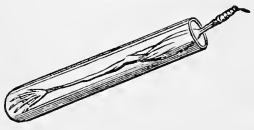


series of half thighs of frogs, he succeeded in decomposing iodide of potassium, in deviating the needles of a galvanometer to 90°, and, by aid of a condenser, caused the gold leaves of an electrometer to diverge. When more delicate tests of the electric currents were made use of, their existence was demonstrated in the muscles of all animals, and even of man himself. Mr. Wilkinson, a gentleman whose very elaborate writings all who devote any attention to these subjects should carefully study (and who, at an advanced age, is still living at Bath, in the enjoyment of his well-earned reputation), in his "Elements of Galvanism," published in 1804, calculated that

the irritable muscles of a frog's leg were no less than 56,000 times more delicate as a test of electricity than that of the most sensitive condensing electrometer. Mr. Wilkinson found that two pieces of zinc and silver, each presenting a superficial surface of $\frac{1}{100}$ inch, produced violent contractions in the leg of a prepared frog; whilst two circular plates of zinc and copper required to be brought twenty times in contact with the condenser, before any sensible divergence of the gold leaves of an electrometer was produced. By comparing the area of these plates, multiplied by the number of contacts with the superficial surface of the minute pieces of zinc and silver employed to affect the frog's leg, he arrived at the conclusion I have just related.

Professor Matteucci availed himself of this circumstance in his contrivance of the frog galvanoscope. This is made, by skinning the hind leg of a frog, and separating it from the trunk, taking care to leave as long a piece of sciatic nerve projecting as possible. The leg is then placed in a glass-tube,

Fig. 9.



the nerve hanging over (Fig. 9). In using this

contrivance, all that is necessary is to let the piece of nerve touch simultaneously in two places the part where electric condition is to be examined. If a current exists, the muscles of the leg will become convulsed at the moment of contact.

In this way the Professor detected a current in man; by making a clean incision into the muscles of a recently amputated limb, and bringing the nerve of the frog-galvanoscope in contact at once with the two lips of the wound, contraction instantly occurred.

In a recent paper, Matteucci has fully corroborated the statement long before made by Mr. Wilkinson of the marvellous sensibility of the irritable muscles of the frog to the stimulus of electricity. For even after an electric jar has been discharged, and the two surfaces of the jar repeatedly brought into communication, so as to get rid of any residual charge, and lose all influence on the more delicate electrometer, its electric equilibrium is still sufficiently disturbed to readily excite convulsions in the frog-galvanoscope.

In pigeons and fowls, as well as in eels and frogs, currents were readily demonstrable; indeed, by alternating a series of the former by approximating their sides, the raw surface of the muscles of which had been exposed by a quickly made cut, Matteucci formed a sort of battery resembling that

made of the thighs of frogs. The result of this experiment has proved that energetic currents existed in hot as well as cold-blooded animals: indeed, more intensely, but very soon disappearing on the death of the animal. These researches completely corroborate the statements and experiments of Aldini made many years earlier, especially that very remarkable one before alluded to, in which he produced contractions of the legs of a frog by bringing them in contact with the tongue of an ox.

By means of the frog-galvanoscope, not only the existence, but the direction, of a current can be discovered; for if the leg be kept for a short time before using it, so as to a little diminish its sensibility, the muscles will contract on *making* contact with the body under examination, if the positive electricity passes from the nerve to the leg, whilst it will contract on *breaking* contact if the electricity is moving in the opposite direction. Using this delicate test for an electric current, Matteucci discovered that the intensity of such currents rises in proportion to the rank occupied by the animal in the scale of being, their duration after death being in the inverse ratio. The Professor discovered, that when a mass of muscle belonging to a living animal, or one recently dead, was placed in contact with a piece of wire so that one end of it touched the tendon, and the other the

body of the muscle, a current could always be detected circulating in the mass in the direction from the tendon to the external surface of the structure. He further demonstrated the very important fact, that everything which decreases the *vis vitæ* of the animal diminishes the evidence of electricity immediately after death. Thus, when frogs were killed by asphyxia, either by immersion in sulphuretted hydrogen, or water freed from air, the electricity detected in their femoral muscles sunk to a minimum; whilst the thighs of frogs whose hearts had been previously removed gave less evidence of the existence of this important agent than those which had not been thus injured.

It is well known that certain fishes possess a peculiar apparatus by which they are enabled to accumulate the electricity developed by the vital processes going on in their structures, and thus produce the ordinarily recognised effects of tension, as shown in the benumbing shock felt on grasping a torpedo or gymnotus. This endowment is, however, peculiar to very few creatures, and all the electricity developed in the frames of other organisms is only to be detected by comparatively delicate tests. It is, however, very remarkable, that in the batrachians generally, especially the frog, an electric current, denominated by Matteucci the "proper current," possessing some approach to tension, and capable of deviating the needle of a gal-

vanometer to 5°, can readily be detected; its direction is always definite from the feet towards the head. This curious and remarkable fact was, I believe, first pointed out by Nobili, but accurately studied by the Pisan philosopher to whose researches I have so often referred.

LECTURE II.

Origin of Animal Electricity—In a State of Equilibrium—In a dynamic State—Traced to chemical Action.—Electrogenic Effects of Respiration and Metamorphosis of Tissue.—Of Decomposition of Salts in the Body.—Electrolytic Effects of such low Currents.—Formation of Ammonium.—Electrogenic Effects of Chemical Union—Applied to the muco-cutaneous and muscular Currents.—Arrangement of acid and alkaline fluids in muscular Structure.—Electrogenic Effects of Evaporation—Of heterogeneity of Structure.—Function of Electricity.—As a cause of Secretion.—Napoleon's Hypothesis.—Failure of Attempts to detect Currents in the Nerves.—Electricity as a cause of muscular Contraction.—Prevost's and Dumas's Views—As the digestive Agent—How far admissible.—Dependence of gastro-hepatic Current on nervous Agency.—Mr. Baxter's Researches.—Theories of Orioli, Meissner, and Herschel.—Zamboni's Piles.—Reputed influence of Electricity on the capillary Circulation.

In my last Lecture I pointed out the universal distribution of electricity in brute matter, and exhibited some of its effects when its equilibrium is disturbed by mechanical, chemical, and thermal influences, and then proceeded to demonstrate its existence in living beings, and succeeded in obtaining it in a state of tension from my own body. The great discovery of Galvani, and the more recent researches of Nobili, Matteucci, and others, next

engaged our attention; and, having adduced sufficient evidence of the existence of free electricity of varying tension in animal structure, we are now prepared to grapple with the difficult and interesting question which next arises.

Having demonstrated the existence of electricity in the animal frame, what is its origin?—whence is it derived? If we for a moment animadvert upon the facts already recounted, we find evidence of the existence of electricity under two distinct forms; one, in which this agent is in a neutral and static condition, that is, in a state of combination, and therefore of rest, capable of being resolved into its two component elements by various mechanical and chemical processes. This form of electricity is possessed by the living fabric in accordance apparently with the general laws of the universal diffusion of this agent throughout all matter, whether dead and inert, or quick and animated with the flame of life. It was this normal compound that I decomposed by drawing a comb through my hair, and the existence of one of whose elements in a free state I demonstrated with the electrometer. We have no means, in the present state of our knowledge, of explaining the origin of this electricity in the body, save by referring it to the fiat of Omniscience.

There is, however, another state in which electricity exists—a dynamic condition, electricity in

motion, or in the state of current. This, evidently, is not anything superadded to the body, but is merely the electricity normally existing in a state of rest and neutral condition, decomposed by some cause or series of causes, by which its positive and negative elements are separated, their attempt at reunion to reconstitute the neutral electricity giving rise to the phenomena we have been investigating. Let us now review some of the processes going on in the body, which, from their nature, appear capable of disturbing the electric equilibrium which would, without their influence, exist alike in the living frame as well as in brute matter.

It is now an incontrovertible fact, that no chemical change can possibly occur without a disturbance of electric equilibrium. Let us, then, ask what processes of this character are going on in the body. The first in point of importance that demands our attention, is the union of carbon with oxygen, to form carbonic acid. We know that, in the respiratory process, this acid, in the form of gas, is, with aqueous vapor, evolved from the lungs, in addition to a considerable quantity which exhales with the perspired vapors from the surface of the skin. It is nearly impossible to determine the quantity of carbon evolved from the body in combination with oxygen, with any great accuracy; but it seems pretty certain, that about thirteen or fourteen ounces are thus got rid

of in twenty-four hours. During this period the greatest proportion is taken in with the ingesta as mere carbon, and undergoes oxidation in some part of the animal frame. By this union with oxygen, carbonic acid is formed and evolved. Now it is demonstrable, that, if we allow a piece of charcoal to undergo combustion in connexion with the condensing-plate of a gold-leaf electrometer, the gold leaves will soon diverge with free negative electricity, whilst the stream of carbonic acid escaping from the burning charcoal carries off with it free positive electricity. This observation we owe to M. Pouillet. It is true that the carbon does not, during its union with oxygen in the animal frame, become red-hot and burn with a visible flame; but this does not constitute a serious objection to our regarding the generation of carbonic acid as one source at least of the excitation of free electricity, for the disturbance of electric equilibrium in the burning charcoal does not depend upon the light and heat evolved, but from the act of union of the carbon with the oxygen. It has, indeed, been suggested by Mr. Wilkinson that the act of respiration is essentially a galvanic operation, and that the cells of the lungs in which the chemical changes proper to this function occur are analogous to the prismatic cells or tubes of the torpedo and other electric fishes. This idea is, I need hardly say, not supported by any anatomical re-

semblance between the organization of the pulmonic cells and the electric tubes of the torpedo; but was evidently simply emitted as an hypothesis necessary to the theory of animal heat promulgated by the very ingenious observer just alluded to. We, however, must not forget that it is by no means proved, that any union of carbon with oxygen does occur in the lungs: it is, indeed, more than probable that this combination occurs most extensively in the systemic capillary system, and that the carbonic acid exhaled in the act of expiration is by no means to be considered as exclusively generated in the lungs.

I have here only alluded to the oxidation of carbon; but we must recollect that hydrogen, phosphorus, and sulphur — elements constituting important and essential ingredients of our food — are also thus burnt off and oxidated in the body. These must, like the carbon, become by this very act sources of free electricity. But a more important influence disturbing electric equilibrium is found in the series of decompositions which, in the physiological condition of the body, are always in action. It is impossible that any two elements can be rent asunder without setting free a current of electricity, which, insignificant as it might theoretically appear, is nevertheless competent to the production of many important phenomena. As one among many examples, I would cite the case

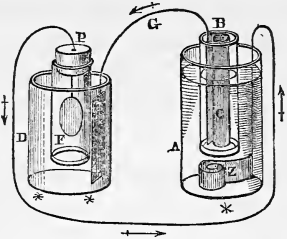
of common salt, which plays so important a part as an article of food, and for which perhaps alone, of all condiments, an universal appetite exists. In addition to the proportion of this substance which enters the blood unchanged and becomes an element of all the secretions, a part is decomposed, and one element in union with hydrogen appears as hydrochloric acid in the stomach; another, in union with oxygen, constitutes, as soda, an important constituent of the bile. What, it may be inquired, can be the influence of these apparently infinitesimal evolutions of electric matter, evolved thus from the resolution of a few grains of salt and water into its elements? But it is easy to produce a mass of evidence to show that these small quantities of electricity are more so in appearance than reality. When we gaze on the electric machine, and listen to the loud snapping, and observe the brilliancy of its sparks, we are apt to fancy that we are dealing with an energetic dose of the agent in question; but all the electricity capable of being evolved from a revolution of the plate or cylinder of the most powerful machine, beautiful and brilliant as may be the phenomena it developes, is incalculably less than that set free by the decomposition of a drop of water or a grain of salt, the real difference consisting in the state of tension or elasticity of the evolved electricity. Dr. Faraday has indeed rendered it probable, that,

during the decomposition of nine grains of water, an amount of electricity is thus set free far greater than that which is called into terrific action in the production of the vivid lightning-flashes and appalling thunder-sound of the dread-inspiring tempest.

But, to descend to positive proof, it has been shown by Becquerel, and subsequently by myself, in a paper read some years ago before the Royal Society, that the electricity evolved during the decomposition of a few grains of common salt was, when properly managed, capable of producing chemical changes which, in the hands of the illustrious Davy, required for their demonstration the vast voltaic battery of the Royal Institution. The element necessary for the production of these phenomena, appears to be simply a weak current with continuity of action.

Let me draw your attention to the glass vessels before you, in which a few grains of common salt have been undergoing decomposition during the last few hours. The current evolved has been made to traverse a solution of hydrochlorate of ammonia. The result of this has been the decomposition of the salt, and the evolution of its curious theoretical base, the compound metal, *ammonium*. It has in the central tube appeared as an amalgam with mercury, a globule of which had been previously entangled in the folds of the

Fig. 10.



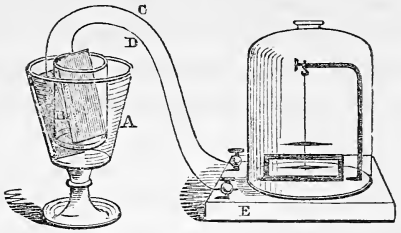
platinum conducting-wire. The compound here appears as a gray ash-colored sponge, like spongy platinum, so light as to float in water. And observe another effect of these weak currents: the amalgam remains in the midst of water unchanged, whilst, under ordinary circumstances, a moment's immersion in that fluid is sufficient to destroy it; the weak current which produced it is effective in retaining it unchanged. By untwisting a wire I cut off the current; chemistry comes into play, the spongy amalgam vanishes

Fig. 10. * Battery or source of the electric current consisting of: A, vessel containing solution of common salt; B, glass cylinder, closed with a plug of plaster of Paris, and containing a solution of sulphate of copper; C, copper plate; Z, zinc plate. * * Decomposing cell: D, vessel containing solution of common salt, having a zinc plate, E, immersed, and connected by a wire, G, with the copper plate, C, of the battery; F, glass tube, closed at the lower extremity with plaster of Paris, containing a solution of hydrochlorate of ammonia, the amalgamated platinum wire immersed in it passing through the cork, and connected with plate Z, of the battery. The direction of the positive current is shown by the arrows.

amidst a torrent of bubbles of hydrogen. Once more let me unite the wires, the electricity from the decomposing salt again traverses the solution; again chemical forces are paralysed, and we shall soon see the spongy amalgam of ammonium and mercury reappear.

We have just noticed the fact that, under the influence of a weak current, salts can be resolved into their component elements. In this way a compound can be separated into its constituent acid and base. Now, it is a remarkable fact, that if an acid and alkaline solution be so placed that their union be effected through the parietes of an animal membrane, or indeed any other porous diaphragm, a current of electricity is evolved. This fact was first noticed by Becquerel, and has since been found to be true, not only with nitric acid and potass, during whose combination he observed this disturbance of electric equilibrium, but with all other acids and soluble bases. I am anxious to demonstrate the accuracy of this statement to you, although I fear the test I shall use, the deviations of the needle of an astatic galvanometer, will not be visible to all. I have here a glass tube closed at one end by an animal membrane — a piece of bladder. I fill it with a weak solution of soda, and immerse it in a glass vessel containing some diluted nitric acid. The soda and acid are gradually combining through the

Fig. 11.



walls of the membrane. I now plunge a plate of platinum into the acid, and connect the wire fixed to it to one screw of the galvanometer. Fixing the wire of a second plate to the other screw, I plunge it into the alkali; the needles of the galvanometer instantly start into motion, and traverse a considerable arc, pointing out the existence of a current of positive electricity from the acid to the alkali, through the conducting-wires. Now, with the exception of the stomach and cæcum, the whole extent of the mucous membrane is bathed with an alkaline mucous fluid, and the external covering of the body, the skin, is as constantly exhaling an acid fluid, except in the axillary and perhaps pubic regions. The mass of the animal frame is thus placed between two great envelopes,

Fig. 11. A, a glass vessel containing a solution of soda, in which is immersed a tube, B, closed at its lower end by a piece of bladder, and filled with dilute nitric acid. Into these are immersed plates of platinum connected by the wires, C D, with the astatic galvanometer, E.

the one alkaline and the other acid, meeting only at the mouth, nostrils, and anus. This arrangement has been shown by Donné to be quite competent to the evolution of electricity: and accordingly he found that if a platinum plate connected with the galvanometer be held in the mouth, whilst a second be pressed against the moist perspiring surface of the body, the needles will instantly traverse, just as they did in the experiment I have shown with the acid and alkali. The current thus detected by Donné at once explains the cause and confirms the accuracy of the celebrated experiment of Professor Aldini, to which I have already drawn attention. I refer to that in which he excited convulsions in a frog by holding its foot in the moistened hand, and allowing the sciatic nerve to touch the tongue. His curious experiment with the head of an ox admits of a similar explanation.

A remarkably energetic current also can be thus detected when the platinum plates are plunged, one into the acid contents of the stomach of an animal, the other into the alkaline secretion of the liver. This gastro-hepatic current is of so very remarkable a character that it will once more occupy our attention.

Founded on the development of electricity by the mutual reaction of acid and alkaline fluids, Baron Liebig has expressed his opinion that the

free electricity in muscular structures could readily admit of explanation. Every one is aware that the blood, in a healthy state, exerts a decided and well-marked alkaline action on test-paper; now, it is remarkable that, although a piece of muscular flesh contains so large a proportion of alkaline blood, still that when cut into small pieces and digested in water, the infusion thus obtained is actually acid to litmus paper. This curious circumstance is explained by the fact announced by Liebig, that although the blood in the vessels of the muscle is alkaline from the tribasic phosphate of soda, yet the proper fluids or secretions of the tissues exterior to the capillaries are acid from the presence of free phosphoric and lactic acids. Thus in every mass of muscle we have myriads of electric currents, arising from the mutual reaction of an acid fluid exterior to the vessels on their alkaline contents. Whatever may be the ultimate destination of this large quantity of electricity, it is at least remarkable, that a muscle should be really an electro-genic apparatus. The view of Liebig on the condition of the fluid of muscles, curiously helps in explaining the presence of electricity in them, announced by Matteucci, although it has been completely repudiated by that philosopher. We have thus two sources of the electricity of muscles—the effects of metamorphosis of effete fibres on the one hand, and on the other the

mutual reaction of two fluids in different chemical conditions. It is certainly curious thus to find a muscle, an organ long exclusively regarded as the motor apparatus of the bony levers of our frames, invested with new properties. Its agency in generating electricity can no longer be denied, and I hope by and by to render it probable that the seat of the generation of a portion at least of animal heat is also in the muscles.

In the course of twenty-four hours, a considerable proportion of watery vapor exhales from the surface of the body. This has been differently estimated, and in all probability is liable to great variations; but from thirty to forty-eight ounces of water may thus be got rid of from the system. The evaporation of this amount of fluid is sufficient to disturb the electric equilibrium of the body, and to evolve electricity of much higher tension than that set free by chemical action. A metallic cup, containing a few drops of water, is placed on the electrometer before me. I now drop in a piece of hot charcoal; a cloud of watery vapor is evolved, and the gold leaves instantly diverge to their utmost extent with free negative electricity. I think this evaporation may probably account for the traces of free electricity generally to be detected in the body by merely insulating a person and placing him in contact with a condensing electrometer. Pfaff and Ahrens

generally found the electricity of the body thus examined to be positive, especially when the circulation had been excited by partaking of alcoholic stimulants. Hemmer, another observer, found that in 2422 experiments on himself, his body was positively electric in 1252, negative in 771, and neutral in 399. The causes of the variations in the character of the electric condition of the body, admit of ready explanations in the varying composition of the perspired fluid. For if it contains, as it generally does, some free acid, it, by its evaporation, would leave the body positively electric; whilst if it merely contains neutral salt, it would induce an opposite condition. The accuracy of these statements can be easily verified by means of the electrometer.

I really cannot help regarding the electricity detected in this experiment by the electrometer as actually due to simple evaporation—and I regard this as a distinct case to the evolution of electricity of high tension in the hydro-electric machine of Mr. Armstrong, which has been so satisfactorily traced by Professor Faraday to the friction of the steam-jet against the sides of the escape-pipe.

It is impossible to quit this part of my subject without calling to mind the fact, that, independently of combustion, chemical action, or evaporation, the mere contact of heterogeneous organic matters is competent to disturb electric equilibrium.

Thus a pile of alternate slices of muscular tissue and brain, with pieces of wet leather interposed, has been found by Lagrave to evolve electricity; and Dr. Baconio, of Milan, has shown that a few alternations of slices of beet-root and wood of the walnut tree were capable of setting free sufficient electricity to excite convulsions in a frog when conveyed to its muscles by means of a conductor formed of a leaf of scurvy-grass. Matteucci has thrown out the suggestion, that the organization of a muscle is possibly such as thus by heterogeneity of structure to account for the development of electricity; he considers the analogy between the voltaic arrangements and the constitution of muscle to be complete, if we conceive the zinc, or oxidizing plate, to be represented by the true fibre; the platinum, or conducting-plate, by the sarcolemma; and the exciting fluid by the blood.

In summing up the foregoing facts, we are, I think, justified in concluding that a mass of evidence has been adduced demonstrative of the actual existence of electricity in three states in the body:—

1st. *In a state of equilibrium, common to all forms of ponderable matter.*

2d. *In a state of tension capable of acting on the electrometer, giving to the whole body a generally positive condition, and arising, in all probability, from the disturbance of the normal electric equili-*

brium by the process of evaporation and respiration.

3dly. *In a state of current, a dynamic condition, arising from the disturbance of equilibrium by the union of carbon with oxygen in the capillary system, and from other chemical processes going on in the body; such currents, although suspected to be everywhere existing, having been actually detected between the skin and mucous membrane, the stomach and liver, and the interior and exterior of muscular structures.*

A difficult question now remains for us to grapple with: having proved the existence of electric currents in the animal frame, what is their office? what purpose are they destined to serve in the animal economy? That they must have some function to fulfil is obvious from their presence; that such function, whatever it may be, is important will be at once conceded from their existence in almost every part of the body. We know that nothing in the meanest element of the universe is made in vain; much less, then, can the philosopher admit that the electricity existing in the masterpiece of the Creator has not some great and destined purpose. From the mysterious character of the agent under consideration, from the astounding effects it developes, from its simulating some of the most occult and remarkable phenomena of the external world, the active ima-

gination of the superficial as well as of the more sober observer has always sought in electricity a clue to most, if not all, of the functions of the body. Some, indeed, have gone the dangerous length of regarding electricity as the principle of life itself, and have dared to place it on a level with the divine essence, which, emanating from the Creator, constitutes what, for want of a better name, we call vitality. These pretensions have been given to this agent from its effects when made to traverse the muscles of recently killed animals, but more particularly when conveyed along the spinal nerves of a recently executed malefactor. This, in the hands of Dr. Ure, in his celebrated experiment upon the murderer Clydesdale, worked on the dead but yet warm corpse a horrible caricature of life; by calling into violent contractions the muscles of the face, all the expressions of rage, hatred, despair, and horror, were depicted upon the features, producing so revolting a scene that many spectators fainted at the sight. But this experiment on the recently executed murderer, striking as it was, merely afforded an additional proof of the susceptibility of the muscles to the stimulus of the electric current; and, when divested of the dramatic interest investing it, becomes not more remarkable than the first experiment of Galvani on the leg of a frog.

Secretion and nervous agency have always been the favorite phenomena which electricity has been called in to explain, and with some considerable appearance of probability. Dr. Wollaston, thirty-six years ago, first suggested from the resolution of salts into their elements under the influence of feeble currents, that secretion depended essentially upon the electric state of the secreting glands; he thus regarded the kidneys as constituting the positive, and the liver the negative, electrodes of the electric apparatus of the body. A curious anecdote is related of Napoleon, who is said by Chaptal to have remarked, on seeing the voltaic battery of the French Academy in action, "*Voilà, l'image de la vie: la colonne vertébral est le pile, la vessie le pole positif, et le foie le pole négatif.*" We must admit that a great *hiatus* exists in every argument which assumes that nervous force and electricity are identical, from the fact that, delicate as are our tests for this agent, it has never been actually detected traversing the nerves. It has indeed been stated that on connecting needles plunged in the nerves of a rabbit with the galvanometer, and exciting the muscles of the limb to contract, currents have been detected. Other observers of high repute have stated that a steel needle plunged in a nerve becomes magnetic during the contraction of the muscle it supplies. Both these statements have

been rigidly tested, and have been found utterly unsupported by the results of careful experiment. These failures must not, however, be admitted as quite conclusive against the existence of electricity in the nerves, although their structures are by no means such good conductors as some other of the animal tissues; for it has been well remarked by Dr. Todd and Mr. Bowman, in their elegant and elaborate work on physiological anatomy, that the insertion of needles into the nerves is not a sufficiently delicate means for collecting electricity, if such exists, for they can scarcely be expected to pierce the nerve-tubes, but would sink in between them and the central axis, from which they would be separated by the insulating matter of Schwann. I shall, however, have again occasion to return to this question.

I dare not occupy your time by an allusion to all the hypothetical notions which have been promulgated regarding the part played by electricity in the animal economy; still there are two or three which, as well from their ingenuity as from the talent of their authors, well deserve a passing notice. Among these, the supposed action of electricity, as the agent which, by traversing the nerves, induces the contraction of muscle, a theory announced by Prevost and Dumas, stands foremost. It was assumed by these philosophers that the nervous fibrillæ traversed a muscle in a direction perpen-

dicular to the arrangement of its fibres, forming a series of loops, either by uniting with each other or with a neighboring nerve. On the influence of the will being directed towards the limb, a current of electricity was supposed to be transmitted along the nervous parallel loops, which would consequently attract each other, and of course, on their approximating, cause contraction of the muscle: this view is evidently founded on the well-known fact of currents moving in the same direction attracting each other, which a single experiment will easily demonstrate.

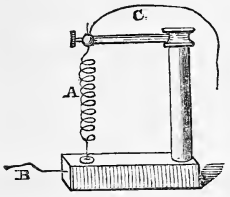


Fig. 12.

I have here a loose helical coil of thin copper wire, suspended from a metallic support. The free end dipping into a cup of mercury. On allowing an electric current to descend the coil, the convolutions mutually attract each other, and raise the end of the wire from the mercury.

It is hardly necessary to allude to the objections which may be opposed to this most ingenious theory; among the most serious is the fact that more

Fig. 12. A, a loose helix of thin copper wire suspended from a support, the free end dipping into a cup of mercury, and communicating by the wire, B, with one plate of a voltaic battery; whilst, by means of the wire, C, the upper end of the helix is in connexion with the other plate.

recent researches of physiologists have shown that the views of its talented authors are not consistent with a correct knowledge of the organization of muscular tissue.

The influence of electricity as an agent in exciting the function of digestion, and, indeed, enabling us in some degree to replace the *vis nervosa*, transmitted by the pneumogastric nerves, by a weak current, has been especially insisted upon by Dr. Wilson Philip. This very indefatigable observer made numerous observations on this matter, and he succeeded in proving that when, in a rabbit that had just partaken of a hearty meal, the par vagum was divided on both sides, the food remained in the stomach unaltered, whilst on allowing an electric current to traverse the course of the nerves to the stomach, digestion was effected. This is just what might, from what is now known of the nature of digestion, have been expected, and a very much less energetic current than that employed by Dr. Philip would have been sufficient. For it is now pretty distinctly made out that the function of digestion in the stomach is an action allied to simple solution, of which water—a proper temperature, and a free acid, the hydrochloric, phosphoric, or both, are the active agents. The feeble current from a single pair of zinc and silver plates is powerful enough to fur-

nish, in a short time, a sufficient supply of electricity to decompose some chloride of sodium or common salt, and to evolve enough hydrochloric acid for the purpose of digestion; and I shall have, indeed, occasion to show in a future lecture that such a current, feeble as it is in point of intensity, is capable of producing most remarkable secondary effects on living tissues, actually effecting very important chemical changes in the parts submitted to its influence. It is true that objections have been started to this theory, but my own impression is that they are not sufficient to invalidate the accuracy of Dr. Philip's statements; and although I do not by any means consider we are justified in admitting with him, that electricity is capable of performing all the functions of the nervous influence in the animal economy, nor in regarding an electric current as constituting the real digestive agent, we nevertheless possess sufficient evidence to induce us to regard a current of electricity as the means by which the saline constituents of the food are decomposed, and their constituent acids, the real agents in digestion, set free in the stomach. The soda of the decomposed salts being conveyed to the liver to aid the metamorphosis and depuration of the portal blood, and cause the separation of matter, rich in carbon, in the form of a saline combination in the bile.

It is remarkable that, although nothing is more

frequently lauded than the certainty of the evidence of natural truths, and although it would appear a simple thing to describe with fidelity and accuracy the results of experiment and observation, still an observer has scarcely had time to announce his discoveries and array his phalanx of facts in a resistless manner, as he supposes, before some other person repeats his experiments, and, perhaps, announces that he has obtained exactly opposite results; such has been the case with Dr. Philip's observations. Mr. Broughton, in particular, obtained nearly directly opposite results. Others have again repeated their experiments, and have sufficiently corroborated the results of the Doctor's researches on the effects of division of the pneumogastric nerves in arresting the digestive process: the influence of the electric current in developing this function after division of the nerves is, however, variously reported. Now, most certainly these discrepancies cannot be admitted as furnishing anything valid against Dr. Philip's views, unless, in addition to the use of the battery, the direction of the current was distinctly indicated; for unless the positive current *entered* the stomach, it would not cause the separation of free acid; as, if the negative fluid entered, free alkali would alone be developed.

There is, in connexion with this hypothesis, a most interesting and important observation of

Professor Matteucci, to whose ingenuity and patience we are so largely indebted: this philosopher introduced a plate of platinum into the stomach of a living rabbit, placed another on the liver, and connected both with a galvanometer; the needles instantly traversed an arc of 20°, proving the existence of a powerful current between the liver and stomach. This, it may be observed, shows the existence of a *current*, but does not prove whether it is to be regarded as an effect or a cause of the chemical changes alluded to; for it has been already shown, that when an acid and alkaline fluid are separated by permeable structures, they actually develope a current of electricity; and as the stomach contains an acid, and the liver an alkaline secretion, this might afford an explanation of the current observed by Matteucci; and had the experiment ended here, this plausible objection would have been a fatal one. But the nerves and vessels passing into the abdomen were divided above the diaphragm, and in an instant the needles of the galvanometer deviated to 3° instead of 20°; and on cutting off the head of the rabbit by a sudden blow, even this little deviation nearly completely vanished. Nothing could be more conclusive than this experiment in proving that the electric current was the cause, not the effect, of the chemical metamorphosis of the saline ingesta, whose decomposition furnished acid to the

stomach and alkali to the liver. Very recently, in a very interesting communication to the Royal Society, Mr. H. F. Baxter has brought forward much and very satisfactory evidence in corroboration of this very interesting observation. He has shown that the only condition necessary to insure accurate and satisfactory results is, to use sufficiently large platinum plates for the purpose of collecting the electricity of the organs under examination. If mere wire points be plunged into the liver and stomach, the galvanometer is often quite unaffected, whilst it readily indicates the existence of a current, if plates of platinum be substituted for the points. The immediate source of this free electricity is still involved in mystery; however rich in conjecture, this most interesting subject is still poor in anything approaching to a satisfactory hypothesis deduced from extended observations. Still it can hardly be doubted that one of the causes which we have already examined is competent for this purpose; but then there remains the difficulty of pointing out the route taken by the current to reach respectively the liver and stomach, for the pneumogastric nerves, at least in man, cannot, from their anatomical distribution, explain this. Is it improbable, I would venture to suggest, that the ganglionic nerves may be more immediately concerned? Does the positive current pass from the solar plexus to the stomach,

and a negative current to the liver? or do the organic nerves alone supply the latter, and the pneumogastric the positive current? All here is doubt and uncertainty, and such must remain until more careful investigations have cleared up the obscurity. All that is certain is:—

1st. That an electric current does exist between the stomach and liver, which nearly ceases on division of the nerves, and completely so with the death of the animal.

2dly. That this current is in all probability competent to the evolution of sufficient free acid in the stomach to enable digestion to go on, an equivalent of soda being determined to the liver.

3dly. That cutting off the nervous supply equally arrests digestion and stops the electric current.

4thly. That on allowing an artificially excited current to enter the stomach, after division of the nerves, the chemical changes necessary to digestion, to a certain extent at least reappear.

Mr. Baxter has rendered it highly probable, that in a living animal, whenever a platinum plate, connected with a galvanometer, is placed in contact with the mucous membrane of any part of the alimentary canal, and another immersed in the blood escaping from the wounded vessels in the immediate vicinity, an electric current can always be detected. It hence appears that in all cases

the secreted matters are always in an opposite electric state from the blood whence they were generated. The electric currents thus derived are strictly physiological, and cease on the death of the animal.

An Italian philosopher of celebrity, Signor Orioli, has hazarded a remarkable theory, which assumes that all the manifestations of life are actually dependent upon a series of galvanic combinations, existing in every organ in the body. He, indeed, regards every glandular organ especially, as made up of a series of such combinations and developing different polarities; he thus assumes that the stomach, kidneys, and skin are by such an arrangement rendered energetically electro-positive, whilst the liver and general expanse of mucous membrane are as powerfully electro-negative. He goes further, and has founded a sort of system of therapeutics on these views; for, believing that disease depends upon an excessive, diminished, or abnormal excitation of the electric polarities of the respective organs, he proposes to treat their several morbid conditions by artificially removing their unnaturally electric conditions. Orioli's views differ from the very remarkable ones promulgated by Meissner, who fancied that during respiration the blood became charged with electricity, which was then distributed by the par vagum and sympathetic nerves

to the great nervous centres. Thus becoming charged, the brain is supposed to excite the action of any organ, by giving a spark to the nerve supplying it. The electricity thus transmitted to the muscles forms around their fibres a kind of atmosphere. Becoming similarly electrified, the fibres repel each other separately in the middle of the muscle, and thus by approximating their ends cause the structure to contract. This very pretty theory has unfortunately no support beyond the fertile imagination of its ingenious author.

Sir John Herschel, in his exquisite Discourse on the Study of Natural Philosophy, has beautifully expressed the possible relation between galvanic electricity and the *vis nervosa*, and hints at the brain being either the organ of secretion, or at least of the application of this agent; adducing in illustration the dry piles, as they are termed, of De Luc and Zamboni, and remarks, that "if the brain be an electric pile constantly in action, it may be conceived to discharge itself at regular intervals, when the tension of the electricity reaches a certain point, along the nerves which communicate with the heart, and thus to excite the pulsation of that organ." By the "dry pile" a ball may be kept in motion for many years, without any obvious waste of power, and some analogous arrangement would

constitute the most constant and economic *primum mobile* of a moving organ which the resources of limited human reason can suggest. Dr. Arnott has also hinted at some such cause being the active agent which keeps up the regular pulsations of the heart.

It is indeed remarkable what an enormous quantity of electricity of high tension is developed by the piles here alluded to. I have one before me consisting of 1200 alternations, made by superposing 400 pieces of paper covered on one side with tinfoil, and on the other with black oxide of manganese. The upper end of this is always charged with negative and the lower with positive electricity; and this little apparatus will, for many years, remain a constant source of free electricity.

Founded on the general law, that bodies similarly electrified repel each other, an hypothesis has been broached, that the circulation in the capillaries is greatly aided by the electric state of the blood. It has been long known that if a vessel containing water, having a very small hole in its base, be connected with the prime conductor of an electric machine, the water will merely escape *guttatim;* but on setting the machine in action, the particles of water becoming similarly electrified repel each other, and the fluid escapes in a continuous stream. In accordance with this fact, it was long ago shown, that if a patient have

a vein opened in the arm, and the blood happen to escape but sparingly, on placing him on a glass stool and electrifying him, the blood will, like the water in the vessel just alluded to, escape *pleno rivo*. There has always been a difficulty in explaining the capillary circulation. Many have questioned, and with reason, the possibility of the injecting force of the heart being competent to exert its influence through the minute blood-channels of the body. The electric hypothesis, to which I have just alluded, would certainly to a great extent meet the difficulty, but must at present be admitted with caution in the absence of absolute proof, however much probabilities may be in its favor. For it must be recollected that when a body is electrified, *its electricity is collected on its surface, and does not extend into its interior;* thus, if a person on a glass stool be connected with the prime conductor of a machine, evidence of a free electricity can be obtained from every part of his surface; but none from the inside of his mouth, for the reason just stated. So the escape of the blood from the vein of an electrified person may indeed be rendered more rapid, without affording the slightest proof that the circulation of the blood in the interior of the body had become influenced.

LECTURE III.

Source of Animal Heat.—Chemical Theories alone incompetent.—Sir B. Brodie's Experiments.—Mr. Wilkinson's Experiments.—Difficulties to Chemical Theory from the Food—From Inflammation.—Electricity as one Source of Heat.—Excitation of Heat by Muscular Contractions.—Development of Electricity by Muscular Contractions.—Mr. Raymond's Researches.—Dr. Paris's Researches.—Question of Connexion between Electricity, Magnetism, and Vis Nervosa.—Theory of Vis Nervosa.—Induced Contractions.—Matteucci's Researches.—Diamagnetic Phenomena.—Action of Artificial Currents on Animal Tissues—On a Piece of Nerve.—Muscular Contractions excited on stopping a Current.—Dr. M. Hall's Electro-genesis—Referred to a Polar State.—Electric Tetanus.—Centrifugal Current excites Motion; Centripetal, Sensation.—Sympathetic and Idiopathic Shocks.—Excitation of Nerves of Special Sense.—Effects of Current on the Intestinal Tube—On Muscles—On Skin.

Having examined the question of the origin of the free electricity of the body, and reviewed the different modes by which the state of normal equilibrium can be disturbed, we passed to the investigation of the possible office of such free electricity, whether existing in a state of current, or in a statical condition. Having criticised some, and briefly glanced at others, of the many ingenious electro-physiological hypotheses which have

been proposed, I shall next endeavor to introduce to your notice some suggestions (for I dare give them no other name) regarding the functions of the electricity of life.

The great interest attached to the question of the source and origin of animal heat has led to numerous and important researches directed with a hope of elucidating the laws of its development, and of discovering its source. It is unnecessary to state that the chemical theory which refers the evolution of animal heat to a sort of slow fire in the system from the union of carbon and oxygen, the former derived both from the ingesta and effete tissues, is the one now generally adopted. This theory, the early development of which we owe to the labors of Laplace and Lavoisier, has been ingeniously illustrated and much extended by the fertile and brilliant talents of Baron Liebig. This celebrated chemist, although he has not added any new *facts* of importance to those first announced by the French chemists, has nevertheless rendered it more attractive and more plausible by the collateral support he has given to it in its relation to the chemistry of the body generally. From his calculations it would appear, that the heat generated by the combustion of the carbon in the body in twenty-four hours would be sufficient to raise 136·8 pounds of water from the freezing to the boiling temperature. It must not be forgotten that two

trustworthy observers had, long prior to the publication of Liebig's views, submitted this matter to the rigid test of experiment. And it is obvious that the mere assumption adopted by Professor Liebig, that the carbon of the food is oxidized in the system, and that from its weight the amount of heat evolved could be calculated, however ingenious and captivating, must give way to sober experiment, if the results are not compatible with the hypothesis. Dulong and Despretz performed their experiments independently of each other, and it is no less remarkable than satisfactory, that they arrived at very nearly the same results by actually measuring the amount of heat generated by a warm-blooded animal in a given time. Dulong thus positively proved that the combustion of the carbon of the food would only account for half the caloric evolved by carnivorous, and for seven-tenths of that evolved by herbivorous animals; and even when the hydrogen was taken into account, full one-fourth was left unaccounted for. Laplace, Lavoisier, and Liebig, in adopting the chemical theory of the evolution of animal heat, took no notice whatever of the nervous agency. Now, I think no one can deny the influence of the nervous system in aiding, to say the least, the evolution of animal heat. Some have, indeed, gone so far as to regard this heat as a sort of secretion from the nerves. Modern physiologists

have so well treated of this matter, and have so satisfactorily shown that we must not neglect nervous agency in explaining the generation of heat, that it is unnecessary for me to allude to it; the pages of Dr. Baly's excellent edition of Müller's great work, and the volumes of Dr. Carpenter, have made this subject familiar to all. Sir Benjamin Brodie long ago demonstrated the fact that, when an animal was killed by dividing the spinal marrow, and artificial respiration maintained, all the chemical changes went on as usual; the venous blood became arterialized in the lungs, the heart continued to beat with vigor; but in spite of all the elements required for the chemical theory of respiration and animal heat being present, the body cooled actually quicker than that of another animal killed at the same time, but not submitted to the influence of artificial respiration. These experiments were many times repeated on several animals, and invariably with similar results. I think no one can read Sir Benjamin's paper in the Philosophical Transactions of the Royal Society for 1811, without regarding them as most conclusive. I am aware that experiments since performed by others have been said to invalidate some of the conclusions from these researches; but even if this be admitted, still his main facts remain uncontroverted, and, as Müller has observed, are convincing; they have besides been

corroborated by the more recent researches of Chaussat. There is indeed, in the present day, too great a tendency in our profession, as well as in the world generally, to rashly adopt opinions tending to oppose previously received views. There may be something in the charm of novelty, but it does not necessarily follow that the most recent statements are of greater value than older ones, unless they are supported by the authority of more careful observation and more extended experience.

The amount of heat required to keep up the temperature of the body to its healthy average is more considerable than, on a superficial view, might appear necessary, and is well illustrated by Mr. Wilkinson's experiments, performed more than forty years ago. This gentleman placed in a large vessel a quantity of water heated to 98°, of about his own bulk, in all twenty gallons, the thermometer standing at the time of the experiment at 66°, the temperature of the water being consequently 32° higher than that of the atmosphere. In forty minutes the water cooled to 90°, having lost eight degrees of heat; but to restore its former temperature required the addition of thirty pounds of water heated to 212°; and to keep it at 98°, or the temperature of the body, the addition of two pints of boiling water each minute was absolutely necessary. On repeating this experiment when the temperature of the air

was 51°, it required the addition of 4½ pints of boiling water per minute to keep it up to the temperature of the body. What must, then, be the amount of heat required to preserve the normal temperature of the human body when exposed to the frozen air of Siberia or Spitzbergen? On the hypothesis of Professor Liebig, the difficulty is supposed to be met by the larger proportion of carbonized food, as fats and oils, consumed by the natives of the frigid zones, thus supplying more fuel for the generation of animal heat. This, however, does not in any way explain the difficulty; for an Englishman traversing the polar ice will have his body of the same temperature as the Greenlander, at least, for anything we know to the contrary, and still without partaking of the train-oil in which his companion luxuriates. Again, the natives of more sunny climes often partake of more fatty and greasy matters than the inhabitant of cooler climes; the Sicilian and Neapolitan, even under their own sunny skies, far exceed the Englishman in the mass of oils and grease they devour, and yet we have no evidence that their temperature is influenced by it. The reindeer seeks its meal of lichens beneath their snowy covering, and yet on this nearly fat-free food maintains its temperature. Again, this theory does not explain how a person preserves the same temperature, although perhaps in the course

of a few days, and under similar circumstances, he is exposed to all the range of temperature the variable clime of Britain can subject him to. All these facts (for they are facts, and not assumptions) show that the mere act of the generation of carbonic acid and water quite fails to account for more than a part of the animal heat.

Pathology, too, furnishes some difficulties to the admission of the combustion theory as the sole exponent of the evolution of heat. Thus, in local inflammations, as of a small gland, ending in a few days by resolution unaccompanied by any evident destruction of tissue, a large quantity of heat is evolved, which appears to me not to admit of explanation without referring to something beyond the chemical theory. I find a curious observation on this matter placed on record by Professor Thompson, of Glasgow, in the Annals of Philosophy for 1813. This gentleman took cold from sitting for some time without removing his wet shoes, and the result was a throbbing pain in the right groin, and an inflammatory swelling of the inguinal glands. He constantly applied, for four days successively, cloths dipped in cold water, removing them when they became dry and warm; the swelling then disappeared, and the Doctor got well. He, however, calculated the amount of heat evolved by this small inflamed and painful spot, and found that it was sufficient to have raised

eight pounds and a half of water from the temperature of 40° to a boiling heat.

As there remains a certain portion of animal heat to be accounted for beyond that which the oxidation-theory will explain, I venture to throw it out as at least a probable hypothesis that this may be one of the functions of the electricity generated by the chemical changes going on in the organism. Admitting the existence of electric currents, which, I think, from the data now collected cannot be denied, they must of necessity traverse some of the tissues of the body. We know, from Matteucci's researches, that they traverse the muscular substance, and have seen how probable it is, that, if not really transmitted along the nerves, such currents are propagated under their influence. Now, if such currents, however weak, do thus traverse animal structures, they must of necessity elevate their temperature: they cannot pass through them without doing so. You have seen how readily a comparatively weak current will ignite a platinum wire; but it may be said this wire is a good conductor, and allows electric discharge to take place readily through it; but no such metallic conductors exist in the body. This is true; but it really appears that the less perfect the conductor—the greater the obstruction (within certain limits) opposed to the passage of the current—the more readily are calorific vibrations produced. Nay

more, if electricity possesses high tension, and is small in quantity, it developes but little heat, seeming to pass with too great rapidity to disturb the inertia of the interstitial ether; just as a bullet fired from a rifle will perforate, without moving, an open door, whilst the same bullet thrown from the hand would instantly cause it to move on its hinges. Thus the really bad-conducting nature of the animal tissues better fits them for becoming elevated in temperature by the passage of a current.

On the table before me is placed some gunpowder, and I transmit the charge of an electric jar through it by means of a good conductor—a piece of copper wire: the powder is scattered about from the violence of the discharge, but escapes combustion. I will now send a discharge through some more gunpowder; but, instead of using a good conductor, will cause the electricity to traverse a piece of string moistened with water. In an instant you see the gunpowder explode. The piece of wet string here undoubtedly acts by retarding the velocity of the discharge, and thus giving time for the excitation of calorific vibrations. A piece of muscle or nerve would have produced similar results. We do not, however, meet in the human body with electricity of such high tension as that contained in a charged jar; but there is no difficulty in proving that the same

law obtains with electricity evolved by chemical action. On the table are two glasses connected by a bent piece of palladium: one of these is filled with an excellent conducting fluid—mercury; the other with a weak solution of common salt, to represent an animal secretion. I now cause a current of electricity, evolved by the decomposition of some nitric acid in these cells, to traverse these two fluids, and you will soon observe that the water will nearly boil, whilst the mercury will be scarcely warm. On bringing a piece of phosphorus near the vessel containing the latter, it is unaffected; but the moment it touches the former, it bursts into flame. From these and other analogous facts, I think it is rendered probable that the amount of animal heat generated in the body, *plus* that which can be accounted for by the combustion theory, is really excited by the passage of the electric currents, whose existence we know has been positively made out in the different tissues of the body. In this way I conceive the heat produced by muscular contraction can be fully accounted for. By means of a thermo-electric combination not thicker than an ordinary acupuncture needle, which could be easily introduced into a limb, M. Becquerel found that, on contracting the muscle into which it was inserted, as in the case of the biceps, by bending the arm, an elevation of temperature occurred sufficient to cause

the needles of a galvanometer to traverse an arc of 0·5. This generation of heat could not be accounted for by a greater determination of blood to the muscle; for, during the act of its contraction, circulation is retarded through it; nor do I see any means of accounting for it without assuming some mechanical cause, unless it be admitted that, to effect the violent contraction, a greater amount of nervous energy is developed in the nervous fibrillæ, and disturbs the electric equilibrium of the surrounding tissues, just as occurs when a magnet is thrust into a coil of wire; the circulation of such currents in the muscular structure would most certainly generate heat, just as they do when traversing water or other imperfect conductors. In this way, I presume, we can explain the mode in which we constantly observe coachmen in the winter thawing their half-frozen arms by a series of violent contractions of those limbs.

It is well known that the temperature of a palsied limb is inferior to that of a sound one. Mr. Earle found the temperature of a paralysed arm to be 70°, whilst that of the sound one was 92°; but, on electrifying the affected limb, the temperature rose to 77°.

We possess some evidence in direct corroboration of the opinion, that determination of nervous energy to a muscle when excited to contract, is

competent to effect the disturbance of its electric equilibrium. M. Du Bois Raymond has stated, that, when the hands are immersed in two basins of water, in communication with the coil of a very delicate galvanometer, and the muscles of one arm suddenly contracted, a current of electricity is developed, and is detected by the movement of the magnetic needles. These researches have been repeated and varied by M. Despretz, who made a report upon them to the French Academy. He found that when a cylinder of platinum, or any other metal, in communication with a galvanometer, was held in each hand, and the fingers of one hand suddenly contracted, so as to grasp the cylinder tightly, the needles of the instrument immediately deviated often as much as 90°. The galvanometer he employed was exceedingly delicate, its wire coil being composed of 1800 convolutions. Unfortunately the sources of fallacy in these very delicate researches are so numerous, that it is scarcely possible to guard against error; and M. Becquerel has expressed his belief that the action of the cutaneous perspiration on the metals of the conductors, will explain these imaginary muscular currents. I confess that I cannot think this conclusion quite just; for when the conductors are held lightly in the hands, no current is detected; it is only when the muscles of one arm or hand are violently contracted, that the galvanometer

needles indicate the disturbance of electric equilibrium.

Although not immediately connected with the subject now under consideration, I could not without regret avoid drawing the attention of the members of the College to the very ingenious and, to my mind, very probable suggestion made eight-and-thirty years ago by our present illustrious president, regarding what may be denominated a mode of economising a portion of the animal heat. From a series of experiments, he found that, as a general rule, the capacity of the fluid excretions for caloric was less than that of the blood from which they were secerned; in other words, that a smaller amount of heat was required to raise them to the same temperature. He thus rendered it probable, that whenever the liver separated bile, and the kidneys urine, from the blood, these new fluids, although possessing the same temperature as the pabulum from which they were formed, yet really contained a less abstract proportion of caloric, and, as a necessary result, a certain amount of heat would be rendered sensible, and must materially aid in preserving the temperature of the body. This opinion, alike remarkable for its beauty and simplicity, has been most unaccountably overlooked by most late writers on physiology, for the experiment on which it was based remains unaffected by the sources of

error which have been shown to invalidate the nearly cotemporaneous hypothesis of Dr. Crawford.

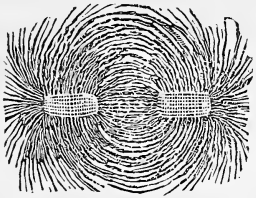
In concluding my remarks on the physiological relations of electricity, I feel that, although a probable, yet by no means a positive, case is made out for its being regarded as the nervous agent, simply from the fact that we have not yet actually intercepted it in its presumed route through the nerves; still, I do not think that all the objections which have from time to time been urged against such a view are by any means tenable. We do not contend for the existence of currents of high tension in the body, and hence the objection that nervous force is stopped by placing a ligature on the nerve, whilst electricity is not, falls to the ground; for, as I have already shown, such currents, if of low tension, and the nerve circulated, are really thus stopped by a ligature. Another objection appears at first sight more plausible: if the trunk of a nerve be divided in a living animal, we know that the limb to which it is distributed becomes paralysed. It has been said that, if the *vis nervosa* and electricity were identical, the paralysis ought to disappear on uniting the divided ends of the nerve by means of a piece of wire or other conductor of electricity, which is well known not to be the case. In reply to this and other such objections, the same answer

may be given, that it is true, that although we can prove the existence of electric currents in many of the tissues of the body, yet it is not contended that such currents are really absolutely identical with *vis nervosa*, but all that is assumed is, that they bear to each other the relation of cause and effect. When an electric current traverses this helix of wire it makes the iron bar placed in its centre a powerful magnet; yet no one contends that electricity and magnetism are, as forces, one and the same thing, but merely that they bear to each other the ratio of cause and effect. If I connect the magnet thus made with another bar of iron by means of a copper wire or any other conductor of electricity, it does not render it magnetic. Nor does any one express surprise at this; because, although electricity can traverse such a conductor, the new force we have developed, *magnetism*, cannot. Yet this is an analogous case to the objection urged against the idea of nervous force being generated by electricity, because we cannot renew it in a paralysed limb by uniting a divided nerve by means of a piece of wire. I confess I have a presentiment that one of the greatest philosophers of the age was correct when he remarked, if magnetism be a higher relation of force than electricity, nervous power may be one still more exalted and within the reach of experiment. I am willing to admit,

that we do not possess a tittle of evidence to prove the existence of electric currents in the nerves themselves, although we know most positively that such currents exist in most other of the animal tissues, and that, further, in certain cases, their existence depends upon the integrity of the nerves: witness the cessation of the gastro-hepatic current upon the division of the pneumo-gastric and sympathetic nerves. Taking for a moment the analogy presented by the electro-magnet, a current of electricity of low tension traverses a wire arranged at right angles to the long axis of a bar of soft iron, and it instantly becomes a magnet of immense power. In an instant you see the bundle of iron wire suspended over the bars before me start as it were into life, and, after a few hasty vibrations, assume a fixed position over the poles. There is no visible connexion between them; and yet, if I forcibly press one end of the bundle of wire, I feel an obstacle to moving it; and on resuming the force applied, it instantly returns to its position. On allowing the current to cease, the induced power vanishes, and the suspended wires obey the tension of the thread. There is, in fact, a radiant power emanating from the ends of these bars when the electricity traverses the wire coil. The directions of such lines of force are beautifully pointed out by scattering some iron filings on a piece of paper held over the magnet thus made by the current. Thus we can

prove the development of a force in these bars

Fig. 13.



of iron under the influence of electricity, albeit none of that agent entered the bars. But this is not all; the magnetism thus excited by electricity can, in its turn, re-excite that agent. There is no difficulty in proving this in a most unequivocal manner. Thus I will excite magnetism in the bars before me, connect the poles with a bar of soft iron, and turn off the electric current. The magnetism will be in part retained as long as the poles are thus connected; but the moment I slide off the armature the magnetism vanishes, almost all polarity having disappeared. Now, during the restoration of this magnetic equilibrium and the return of the bars to their passive condition, a contemporaneous disturbance of the electric equilibrium of the convolutions of wire wound on the iron bars occurs. I will now render the bars magnetic, connect the poles with the armature, break the battery connexions, and place the terminal wires of the coil surrounding the bars in connexion with the large galvanometer at the other end of

the table. The needle is now at rest. By sliding the armature off the poles, I destroy the magnetism, and in an instant the galvanometer needle moves on its axis through an arc of 90°, demonstrating the truth of the assertion I made. Thus, then, an electric current excites magnetic force, and a magnetic current in its turn excites electricity.

Let us, then, see what light *analogy* can throw on the connexion of electricity with the nervous influences; and I would ask, *May not one of the uses of the electricity so freely developed in the body, especially that existing in the muscles, be to excite in the nervous cords the* vis nervosa, *just as currents, if passing near a bar of iron at right angles to its axis, excite magnetism? May not this* vis nervosa, *or nervous polarity, excite the contraction of a muscle without actual contact with its fibres (for we know that the fibrillæ of nerves lie upon, but do not communicate with, the ultimate fibres of muscle), just as the invisible lines of force emanating from the bars of a magnet act upon the suspended bundles of wire or iron filings? Lastly, may not such nervous force again induce electric currents in any glandular or other organs, just as magnetism in motion will re-excite electricity? thus accounting for what cannot be questioned, the existence of electric currents in certain organs, exclusively excited by, or depending for their existence*

upon, the integrity of the nervous influence of the part.

I feel that all this is mere hypothesis, but I think it a plausible and probable one; and believing that the *vis nervosa* is not electricity, although developed under its influence, I suggest it on the strong grounds of analogy, with a firm expectation that the time will come when some such view will be shown to be correct.*

* Since this Lecture was delivered at the College, Professor Matteucci has laid before the Royal Society some further observations, in which he has arrived at conclusions strongly corroborative of the statement I then ventured to make. He says:—

"We have thus every reason to conclude that the electric organ of the torpedo, and of all the electric fishes, is composed of a great number of elementary organs, and that the elementary organ is nothing else but a nervous fibril in contact with a small cell filled with albumen. And since this cell gives an electric shock when it is subjected to nervous action, we are compelled to admit, that under nervous influence the two opposite electricities separate to be instantaneously reunited. This relation between nervous influence and electricity is, without doubt, of the same nature as that which exists between heat and electricity, between the electric current and magnetism. It is in studying the production of electricity in the different electric fishes, together with the distribution of nervous filaments in their electric organs, that we arrive at a better understanding of this relation between nervous force and electricity. Thus we see in the torpedo and gymnotus —the two electric fishes best known physically and anatomically —that the nervous filament always ramifies in the electric organs of these fishes perpendicularly to the axis of the prisms of these organs. Besides which, we know that the extremities or poles of the electric organs in these two fishes are situated at the extremities of the prisms; in effect, in the torpedo these poles are

I cannot help regarding the phenomenon of what Matteucci has termed "induced contractions," as corroborative at least of the opinion thus advanced. I have said that these manifestations of force we term magnetism and electricity, although not identical as forces, nevertheless mutually excite each other: now, something of this kind has been made out by Matteucci in the case of muscular contractions. This philosopher allows the nerve of his frog-galvanoscope (Fig. 9) to lie across the naked muscles of a frog's thigh: on passing a feeble current of electricity through the latter, convulsions occur, not only where they would be looked for, in the leg traversed by the electricity, but where they would not be expected, in the leg whose nerve reposed on the electrified thigh. Now, this could not have arisen from any electricity running down the nerve to the leg; for the very same result occurs

the ventral and dorsal surface, while in the gymnotus the poles are at the head and tail of the animal.

"It will be seen from this, that in this action of the nervous force, as exercised in the electric organs of these fishes, it follows the same law in developing electricity as does the electric current upon magnetic bodies. In effect, each prism of these electric organs cannot be considered otherwise than as a pile of elementary organs, upon each of which a nervous filament is spread normally to the axis of this pile. Now, a cylinder of cast iron enclosed in a helix of metallic wire, and traversed by the electric current is evidently an apparatus analogous to a prism of the electric organs of the fish, at the moment when the nervous influence excites the discharge."

when a thin piece of mica or a layer of turpentine, both non-conducting bodies, is placed between the nerve and the thigh of the electrified frog. (Phil. Trans. 1847, p. 231.) Nay, it is by no means necessary to apply electricity at all; for if the muscles are made to contract by irritating the spinal marrow of the frog, or even of a rabbit or dog, the claw of the galvanoscopic frog becomes convulsed. With true philosophic caution, Matteucci hesitates to regard this curious discovery as absolutely demonstrative of the evolution of electricity in the act of muscular contraction; and I may adduce it in evidence of the existence of a power exciting nervous force, or something analogous, under similar circumstances to those in which electricity developes magnetism.

Let me now say one word regarding the last of the host of valuable contributions made by our illustrious countryman, Dr. Faraday, to experimental science. He has shown that this excited power, this effect of electricity, this magnetism, is an agent of far more universal sway than was ever previously guessed at. The lines of force emanating from the poles of a magnet are potent in their effects upon all forms of matters. Some metals, as iron, nickel, cobalt, and paper, cork, and even glass, among other bodies, obey the direct attraction of the poles, and, if free to move, arrange themselves in the direction of these lines of force, and take up their place in a plane con-

necting the two poles: such bodies are essentially then *magnetic*. But there are other bodies, including the largest proportion of all varieties of natural substances, which are repelled, instead of being attracted, by these poles; and, when free to move, arrange themselves in a direction at right angles to the magnetic lines of force, as in a plane perpendicular to one connecting the two poles. I will place in the little cradle suspended to the slender thread before me, a bar of iron; I now turn on the electric current, and in an instant the iron places itself in a line connecting the two poles. But if I break connexion with the source of electricity, and replace the piece of iron by one of bismuth, it will remain quiet; but the instant I render the bars magnetic, the bismuth will begin to move, and will rest in a direction at right angles to the poles. Such bodies are termed by Dr. Faraday diamagnetics. Thus iron and magnetic bodies, being equally attracted, point with regard to the poles

Fig. 14.

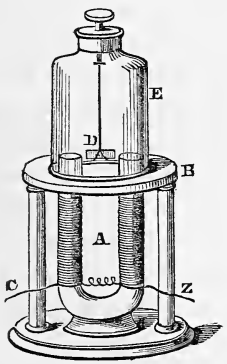


Fig. 14. A, a powerful electro-magnet capable of being connected with a voltaic battery by the wires C Z, its poles passing through a board B, supported by a frame-work in which the

of a magnet north and south, whilst bismuth and diamagnetics, being equally repelled, point east and west. But the most remarkable effect flowing from these discoveries is, that all organized bodies are thus acted upon by the magnet: not only will a piece of wood, a leaf, or an apple, thus submit to its influence; but if a man were fully suspended between the poles of a sufficiently large magnet, he too would obey its influence, and point east and west! Who can predict what wondrous results may flow from this last great contribution to natural science?

We have next to examine the direct and indirect influence, on organized structures, of electric currents artificially excited; for it is obvious that by extending our knowledge of such actions we may expect, not only better to understand and appreciate the effects of such currents upon the human body, but be better enabled to recognise their functions when generated by the functions of the living fabric, independent of external and artificial causes. The successful examination of this question can only be looked for when weak currents of electricity are employed, as by using

magnet is enclosed; the bismuth or other substance to be examined, D, is suspended between the poles by a few fibres of unspun silk, from a wire passing through the top of a bell-glass, E, which answers the purpose of cutting off the influences of currents of air.

those of high tension the mechanical violence produced by their traversing organized structures, almost completely masks their physiological effects. Experiments of this kind are generally best made on those martyrs to science, the batrachian tribe; for frogs and toads, after decapitation, or division of the spinal marrow in the neck (a precaution which divests such researches of the charge of cruelty), so long preserve their irritability to stimulants, that they are better fitted for such observations than warm-blooded animals.

Galvani's classic experiment I have already described and repeated, and I have now to draw your attention to the curious fact, that a current of electricity need not, as he supposed, traverse the whole extent of a nerve to its distribution in the muscles, to produce contraction; if merely a portion of the trunk of a nerve be included in the circuit, the contractions will occur. I have before me the prepared leg of a frog; and I will cause a current from a pair of copper and zinc plates to traverse half an inch of the sciatic nerve, taking care that it shall not enter the femoral muscles: immediately, as you see, contractions occur. This experiment is one of no little physiological importance, as it would appear to point out a further relation between the so-called *vis nervosa* and electricity; as the disturbance of the electric equilibrium of the nerve would be the necessary result of the passage of this limited current.

I will now cause a current of electricity to traverse the coil of a galvanometer, and then to pass through the prepared leg of a frog in such a direction that the positive electricity may enter the limb by the sciatic nerve and leave at the toes. As might be expected, contractions instantly occur, but as instantly cease, although the electricity continues still to traverse the lime, as shown by the needle of the galvanometer. I now break contact with the battery, *and again contractions occur*, although, as indicated by the galvanometer, the current had ceased to traverse the limb. It is evident from this experiment, that the nerves must undergo some change during the passage of the current—a change probably connected with an altered arrangement of some of their organic elements, which for the time paralyses these structures to the influence of the current. On arresting the passage of the electricity, the coercing influence of this agent ceases, and the return of the organic elements of the structure to their normal state produces, or at least is accompanied by, a second contraction. If, however, the current be allowed to traverse the nerve for twenty minutes or longer, no contraction will be manifested on breaking contact, the change produced in the structures being permanent, and they are left paralysed to the further influence of the agent.

These secondary contractions in the frog admit in part of an explanation by supposing that, under the coercing influence of the current, some change occurs in the normal electricity of the tissues traversed by it. This may be rendered clearer by assuming that the ultimate particles of the animal electricity are spherical, and, like those of magnetism, as conventionally assumed, have opposite properties on their two sides, one hemisphere being positive and the other negative. Thus, if in this diagram P and N respectively indicate these hemispheres, the particles must, to be perfectly neutral, be arranged thus:—

NP+NP+NP+NP
PN+PN+PN+PN.

Now, on an artificial electric current traversing such an arrangement, one series of these atoms must undergo a semi-revolution on their own axes, and the following polar condition would be produced—

PN+PN+PN+PN
PN+PN+PN+PN,

and would continue as long as they were under the coercing influence of the current. The instant, however, it ceased, the similar sides of the electric atoms would repel each other, and a semi-revolution would occur, causing eventually the oppositely

electrified hemispheres to be in contact, and thus the previous state would be restored. A too long continuance of the current would render this state one of permanent paralysis, not recovering itself by the mere passive effect of arresting the current, nor exhibiting any sensibility when submitted to a repetition of the current itself. Thus, in a frog's leg, long submitted to such an influence, contractions cannot be produced by the application of silver and zinc coating to its nerves and muscles. It was, however, discovered by Volta, that unless positive mechanical injury had occurred, the sensitive state of the structures could be generally restored, by allowing a current to traverse the limb in the opposite direction to the first: just what might be expected on this hypothesis, for this current would restore the previous coerced atoms to their normal condition. Of course this reasoning is, *quoad* organized structures, completely hypothetical, but it is absolutely demonstrable in the case of magnetism—a force probably, as I have before hinted, more allied to the nervous power than any other. For we can thus induce magnetic polarity, destroy it, and reverse it, in a bar of iron at will. Now, in the living animal the vital force is generally competent to immediately remove the paralysed state produced by a continued current, and even in the leg of a

dead frog it is often restored by repose, unless, as I have already shown, it be too long continued.

In the human subject a phenomenon precisely analogous is often observed; for in cases of paralysis of motion, when an electric current has been applied sufficiently strong to produce pretty powerful contractions of the muscles, the patient is sensible, often for hours afterwards, of thrilling and convulsive motions and sensations in the paralysed part, often closely resembling the immediate effects of the current. This is often well shown in cases of paralysis of the portio dura.

It is, however, quite certain, that some physical change in the ponderable atoms traversed by the current does really occur, independently of those which we have assumed to be produced in the electric atoms. Such a change, although invisible to the naked eye, can, however, be readily shown to be effected by a very remarkable experiment.

Here is the ordinary apparatus employed for collecting the elements of water when separated by the electric current. On connecting it with the battery, torrents of hydrogen and oxygen are given off from the platinum plates, and rise in the tubes placed over them. You can readily distinguish the oxygen from the hydrogen by the

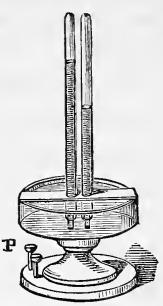


Fig. 15.

respective bulks of the gases; for, as you are aware, two volumes of hydrogen and one of oxygen are evolved from every atom of water. I will now separate the wires from the battery, and refill the tubes with water acidulated with sulphuric acid, and prove to you the curious fact that, although the platinum plates seem unaffected by the operation, still that they have undergone a remarkable change, which they retain even after being washed with boiling water. You know that if a piece of amalgamated zinc be plunged into dilute sulphuric acid, no visible change occurs until some electro-negative metal, as platinum, is brought in contact with it, when bubbles of hydrogen will, as I now show you, be evolved from the platinum, the zinc slowly undergoing solution; the hydrogen being evolved at the platinum surface, whilst the oxygen combines with the zinc under the influences of the electric current evolved. The physical change experienced by the platinum plates of the apparatus used for decomposing water is of such a character, that if I repeat the experiment I have just shown you with it, hy-

Fig. 15. Apparatus for the decomposition of water. The tubes, O H, are inverted over plates of platinum connected with the screws, P.

drogen will be evolved from both platinum plates, but in nearly double the volume from one as from the other. This remarkable experiment I think most clearly proves the existence of some physical change produced by the previous transit of the electric current in the surface of the refractory metals of which the plates are composed, and therefore renders the admission of an analogous change in the more yielding organized structures less difficult.

Dr. Marshall Hall has recently described, in a paper read before the Royal Society, some phenomena of a character apparently to me identical with those just described. This laborious cultivator of physiological science allowed a weak current to traverse the nerves of a frog's leg, and thus to reach the muscles, for some time; then on stopping the current, and connecting the nerves and muscles by means of a conductor, contractions occurred. Dr. Hall explained this (at least so far as I could follow his paper, which was read under every possible disadvantage) by assuming an electro-genic power in the nerves themselves. I confess I doubt the necessity for such a supposition; for the contraction of the muscles on making the connexion would be sufficiently accounted for by the restoration of the electric equilibrium of the tissues disturbed by the primary current. Indeed, the result of the well-known

experiment of passing a current through a piece of wet paper instead of a frog, seems precisely the same. If a band of paper be moistened with water, and employed to connect the two ends of a battery for some minutes, it will, on removal, be found in a polar state, one end being negative, the other positive, and on connecting the ends with a galvanometer the needles instantly traverse. I regard Dr. Hall's frog in the same condition as the band of paper, only being provided with irritable fibre furnishes a test of its own induced electric state, and renders the galvanometer unnecessary.

If a sufficiently powerful current be allowed to traverse the leg of a frog in such a manner as to have its direction alternately reversed, the limb is not merely paralysed to the subsequent influences of a weaker current, but is thrown into a state of tetanic spasm, and on the cessation of the currents is left perfectly rigid, and quite insensible to the stimulus of a weak current. Connected with this observation, a remark has been recorded by Richerand, that after severe convulsions the muscles are left in a state but feebly sensible to the stimulus of an electric current. The production of this artificial tetanus may be readily shown by transmitting alternately currents from the apparatus before you—the electro-dynamic machine—whose construction will occupy our attention in a

future lecture. The legs of the frog are now, as you see, in a state of intense tetanic convulsion; the toes are extended as if the dead limbs were suffering tortures, and on testing them with the zinc and silver plates they remain unaffected. Mere direct currents, if long continued and energetic, will produce this tetanic state, and then, like the paralysed state before referred to, will be generally removed by changing the direction of the current: indeed, in frogs rendered tetanic with *nux vomica* the spasms ceased during the passage of an artificial current, and Matteucci noticed the same result in the case of a tetanic patient.

The effects of an electric current upon a nerve, and consequently on the muscles it supplies, remarkably differ according to the direction it pursues. This observation is one of the greatest interest and importance; and in repeating it, the only precaution that is necessary to observe all the phenomena I am about to describe, is that already pointed out, of using as weak a current as possible. I shall now make use of an apparatus consisting of a single pair of copper and zinc plates excited by hydrochloric acid greatly diluted.

It must not be forgotten that mere muscular tissue is susceptible to the stimulus of electricity, quite independently of its passage through the

nerves supplying the structure. Hence, when an electric current is transmitted through a limb, transversly to the direction of the nervous supply, contractions will occur from the direct influence of the current on the muscular tissue. It appears, however, that a more energetic current is required to exert this direct influence, than when it is allowed to reach the muscles in the presumed course of the *vis nervosa*, or, in other words, in the direction of the nervous ramification.

Muscular contractions are developed in the most perfect manner when the positive current travels the limb in the presumed direction of the *vis nervosa;* hence, in repeating Galvani's experi-

Fig. 16.

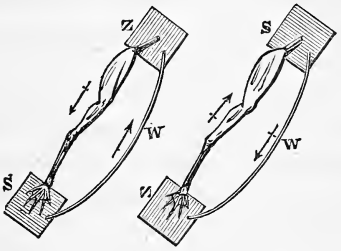


Fig. 16. Z and S represent respectively plates of zinc and silver, on which the sciatic nerves and the paws of the prepared legs of a frog repose. The plates are placed in electric communication by the curved wire, W. The arrows show the direction of the positive current which traverses the limb in the direction of the nervous ramifications in the first leg, and in the second it passes in an opposite direction.

ment, the contractions are more powerful when the zinc is connected with the lumbar nerves, and the silver or copper plate with the muscles of the toes, because in this arrangement the positive current traverses the arc from the silver to the zinc, and then down the limb back to the copper. If care be taken to keep the leg of the frog sufficiently long to diminish its irritability, no contractions whatever will ensue on making contact between the zinc and copper plates if their direction be reversed; but in this case contractions ensue on breaking contact, from the rearrangement of the normal electricity in the direction of the *vis nervosa*. In describing these currents I shall for the future speak of a positive one, when moving in the direction of the nervous ramifications, as a *direct*, and when in the opposite direction as an *indirect* current.

I have already stated that an electric current of sufficient tension may excite contractions in a limb, either by its passing in the course of the nervous ramifications to the muscular tissue, or by acting directly upon this, independently of being conducted by the nerve structure. Professor Marianini, who has particularly drawn attention to this circumstance, has termed the shock or contractions produced by the discharge of an electric jar, or the passage of a voltaic current through the muscular structures independently of the

nerves, the *idiopathic shock;* whilst he has applied the term of *sympathetic shock* to the influence on the muscles conveyed by the current traversing the nerves. Thus when an electric jar is discharged *down* the arm, both these shocks are produced; whereas, when discharged *up* the arm, that is, in a direction opposed to the direction of the nervous ramifications, the idiopathic shock is alone felt. In the former case the sensation experienced according to these views is twice as intense as in the latter. Hence, if with the right hand a person touches the outside or negative coating of a charged jar, and with the left touches the knob or positive surface, he ought to experience a much more intense sensation in the right arm than in the left; for in the former the positive electricity runs down the arm and produces both the idiopathic and sympathetic shock, whilst in the latter the idiopathic shock is alone experienced. It is very difficult to accurately test the truth of these views, although it must be confessed that theory is much in their favor.

It seems quite certain that, *cæteris paribus*, nerves only convey the influence of a current (when sufficiently weak to barely overcome the resistance of the imperfectly conducting structure) to the muscles they supply, in a given and definite direction. It further appears that a mixed nerve of sensation and voluntary motion will only obey

the stimulus of a feeble electric current to excite contractions when acted upon by a direct current —an indirect current exciting only painful sensations and no motion.

If in a living frog the legs be separated from the trunk by the division of all intervening structure, except the sciatic nerves by which communication is kept up between the several portions, and a current be transmitted, very instructive results bearing upon these facts are observed. For when a direct current is allowed to traverse the body of the animal along the nerves to the legs, violent convulsions occur, whilst if the direction of it be reversed, no motion whatever occurs, but the frog will express its sense of pain by audible croaking. The application of the galvanic stimulus thus lends much support to the opinion of the really double structure of the so-called nerves of sensation and voluntary motion; for we have seen that when travelling in the direction of the ramification of the nerves a *centrifugal* motion is excited, and when in the opposite direction a *centripetal* sensation is developed, and not the slightest motion occurs if all communication with the spine is cut off. This fact admits of a ready explanation on the views of Dr. Marshall Hall, to whose patience, ingenuity, and talent, this portion of physiology stands so deeply indebted.

Matteucci and Lauget have shown that this

effect of electricity may be conveniently applied to test the nature of a particular nerve, as far as its motor and sensitive function is concerned; for if a current of low tension traverse a spinal nerve after the careful division of its anterior root, not the slightest motion ensues, whilst if the other root only were divided, contractions would instantly occur.

When a current is allowed to act upon the nerves of special sense, it seems simply to produce the effect of exciting their proper function. Thus if an electric current be allowed to pass from one ear to the other, a loud noise is audible; if through the eyes, flashes of light are seen; if the tongue, an acrid taste, &c. According to Grapengiesser, these results are always best noticed when the positive current enters the organ: thus on making contact, in that ear where the positive electricity enters, the loudest sound is heard, whilst on breaking connexion with the battery the sound is most audible in the other ear: just what might have been expected from the observations already made on the action of currents on nerves.

It must not be supposed that the feeble currents of electricity we have employed are alone active on frogs, for effects sufficiently energetic are produced by them on warm-blooded animals, and I hope to produce evidence, when speaking of the medical application of these agents, to show

that important remedial effects may be thus developed. I shall now content myself with adducing two or three recorded facts in illustration of this position.

Aldini placed a zinc plate in the mouth of a recently killed ox, and a piece of silver in the anus; on connecting them with a piece of wire, the abdominal muscles were convulsed, and a discharge of fæces occurred. This curious experiment was repeated by Achard of Berlin on himself; he experienced, almost immediately, pain in the pelvis, and soon after the contents of the bowels escaped. Humboldt tried this experiment with a linnet which was lying on its back exhausted, and in fact dying; no result occurred until the metal placed in its beak was connected with that in the cloaca, when, in an instant, the bird appeared to be resuscitated; it opened its eyes, stood up, flapped its wings, breathed for eight minutes, and then quietly died. He then tried an experiment on himself by blistering a small surface over both deltoid muscles, placing on the raw surfaces plates of zinc and silver. On connecting the metal with a conductor a distinct shock and contraction of the muscles were felt, followed soon after by others rather weaker. He also observed that the blister to which the silver was applied, soon healed up, whilst that to which the zinc was applied discharged for a long time,

and if previously nearly dry before the application of the zinc, had its discharge renewed. I shall have occasion soon to allude to some very remarkable consequences I lately observed on repeating this experiment on some patients in the wards of the hospital.

The effects produced by electricity upon the different tissues of the living body will of course vary with its intensity and quantity; for if these be at all considerable, convulsions and contractions, more or less violent, are excited in all muscular structures, whether composed of striped or plain fibres, and whether under the dominion of the will or not. These movements are accompanied by painful sensations, if the part acted upon by the electricity be supplied with nerves of sensation. If a series of powerful currents, rapidly succeeding each other, be transmitted through a limb, a state of complete tetanic convulsion is excited, accompanied, especially if the currents be alternately reversed, with sensations of intense pain. Thus, if any person, having his hands moistened with water, grasp the conductors of the electrodynamic apparatus before me, a rapidly repeated series of alternating currents will pass through his arms, contracting the muscles so forcibly with almost tetanic rigidity, that it would be impossible to unclasp the hands and leave hold of the conductors. This state is accompanied by the most in-

tensely painful sensations; so severe, indeed, that it was once soberly suggested by the contriver of one of these machines, for adoption in the army as a substitute for military flogging. If the influence of the electricity be limited to a particular muscle, contraction of that organ will alone ensue; thus, if the charge of a Leyden jar be transmitted from the scrobiculus cordis to the back, it will only influence the diaphragm, causing that muscle to contract violently, and expelling the air from the lungs with a loud shout.

When a current of electricity is made to influence the skin as exclusively as possible, great congestion of the cutaneous capillaries is produced, the surface becoming vividly reddened. If electricity of tension is employed, as by drawing large sparks from a person seated on an insulating chair, not only is this erythematous state produced, but a copious eruption of white papulæ, or rather wheals, is excited, forming indeed a good specimen of Urticaria febrilis.

LECTURE IV.

Medical Electric Apparatus.—Common Electric Machine—Mode of exciting.—Origin of Electricity in the Prime Conductor.—Positive Sparks.—Insulating Chair—Substitute for.—Galvanic Trough—Mode of exciting.—Induced Electric Currents—Mode of exciting.—Primary and Secondary Currents.—Description of Electro-Magnetic Machine with double Current—with single Current.—Electricity of different Tensions—Employment of Electricity at Guy's Hospital.—Influence of single Pair of Plates.—Electric Moxa.—Rationale of its Action.—Treatment of indolent Ulcers.—Removal of Malignant Structure.—Dr. Babington's Researches.

I PROPOSE to-day making a few remarks regarding the forms of apparatus employed in the application of electricity and its modifications, to the treatment of disease. Of these, the common electrical machine and the electro-magnetic apparatus are the most important: by aid of the former we obtain small quantities of electricity in a state of high tension; and by the latter we obtain very large quantities of a lower tension, but still far higher than when elicited from the galvanic trough, which, indeed, is now very seldom employed for medical purposes.

You are all well acquainted with the construction of the common electrical machines; but a

few remarks in connexion with their mode of action may not be regarded as altogether useless.

The electrical machine consists of a revolving cylinder or plate of glass, submitted to the friction of cushions or rubbers. It matters very little what form of machine is employed. As a gene-

Fig. 17.

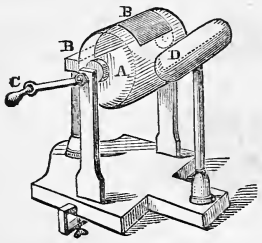
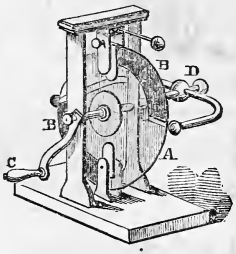


Fig. 18.



ral rule, a plate machine is, for equal size, of far higher power than the cylinder. The arrangements of the latter are, however, simple, and are, perhaps, more easily managed by the uninitiated. There is also an advantage on the score of economy, as old cylindric machines are readily to be procured at low prices, and, as a general rule,

Fig. 17. Cylindric electric machine.

Fig. 18. Plate electric machine. In both figures the same letters are affixed to the most important parts. A, the revolving electric, rotated by the handle C, and submitted to the friction of the rubber B B. The prime conductor, D, affords the means of collecting the electricity excited, in a state of high tension.

a well-worn cylinder is far preferable to a new one. Plate machines are, on the contrary, less common, and consequently must generally be purchased new. Whichever form is employed it is useless employing a plate of a less diameter than a foot, or a cylinder of less than five or six inches.

There is some little tact required to elicit the full power of an electric machine; and, from want of this, you will frequently find some persons quite fail in exciting any amount of electricity, even from the best-constructed machines. This art is, however, soon acquired. When the machine is required for use, the prime conductor and rubbers should first be removed, and the machine placed sufficiently near a good fire to become completely dry and warm. The surface of the glass should then be slightly rubbed with a piece of tow or flannel soaked in olive-oil, any adhering black spots from old amalgam being scraped off. By means of a dry and warm linen cloth, the oil should then be wiped away, and the polished surface of the glass is thus left clean and free from moisture. The cushions, if covered with amalgam, are then to be rubbed with a piece of brown paper, so as gently to remove the oxidised surface; but if not sufficiently covered, a little amalgam (made by melting together zinc two parts, tin one part, with mercury six parts, made into a

paste by triturating it in a mortar with a little lard) must be rubbed into the surface of the cushions with the handle of a knife or a piece of smooth wood. The silk flaps are to be wiped clean, and the rubbers adjusted to the plate or cylinder. On revolving the latter, a rustling noise will be heard, accompanied in a darkened room by vivid flashes of blue light, whilst a strong phosphorous-like odor of *ozone* becomes perceptible. The prime conductor is next to be replaced, taking care that its insulating support is perfectly dry, and even slightly warm: the instrument is then fit for use. You will, however, not unfrequently find, that although you may have taken the precaution to connect the rubber with the table or floor, by means of a metallic conductor, still that little or no electricity is obtained on revolving the glass. This will generally be found to depend upon the badly conducting table or floor, by which a sufficiently ready means is not afforded for the complete restoration of the electric equilibrium of the rubber, when destroyed by the friction of the revolving cylinder or plate against its surface. This difficulty is best overcome in London and large towns, by connecting the rubber, by means of a long copper wire, with a branch of the leaden pipes through which the house is supplied with water. By this plan a ready communication is afforded by a good con-

ductor with the great reservoir of electricity—the earth.

Having thus got the machine in good action, on revolving the cylinder or plate, and presenting the hand or a piece of metal towards the prime conductor, a series of vivid sparks, attended with a loud snapping noise, will pass between them. In this arena I am sensible that any remark connected with the theory of the excitation of electricity by the machine would be quite misplaced, as I feel that all I have the honor of addressing must be most fully acquainted with everything pertaining to this branch of physics. There is, however, a popular error so generally believed, that I must venture to allude to it; the error consists in regarding the electricity of the prime conductor as derived from the revolving glass, the latter being regarded as pumping electricity from the rubber, and thence from the earth. Now, the fact is, that not an atom of positive electric matter leaves the glass to pass to the conductor. The cylinder or plate, rendered positive by friction against the rubber, merely acts upon the electricity naturally present in the prime conductor by *induction*, decomposing it into the component elements, attracting the negative fluid, which, accumulating in a state of high tension, or elasticity, darts off towards the cylinder to combine with the positive fluid free on its surface, reconstituting the neutral

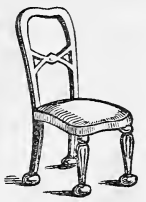
compound; the prime conductor is thus left powerfully positive, not by acquiring electricity from the cylinder, but by the abstraction of its own negative element. Again, the sparks which appear on approaching the hand to the conductor are often called *positive sparks*, when, in truth, they are nothing of the kind, being, indeed, a series of luminous discharges formed by the union of the negative electricity of the body, which is held near the conductor, with the free positive electricity of the latter.

In addition to the electrical machine itself, a pair of directors, or rods of brass, furnished with balls of brass and glass handles, together with a few yards of common copper bell-wire, or brass chain, will be required to connect the patient with the machine, or to convey the discharge of a jar through his body. The jar itself need not have more than a square foot of coated surface, and indeed one much smaller is often sufficient.

There is one piece of apparatus which is very essential, being in almost constant requisition—I mean the well-known chair with glass legs, on which a patient may sit and be completely isolated from all electrical communication with the earth. This is an expensive, bulky, and fragile contrivance, and hence is the most inconvenient of all the electrical appliances. I advise you, however, not to trouble yourselves with the very clumsy

contrivance, which you will generally find at the instrument maker's; as any ordinary chair can be at once rendered most effectual in insulating any person, by merely placing each of its four legs in a thick cup of glass. These may be procured at any of the glass shops, by merely asking for four thick round glass salt-cellars in the rough state in which they are sent from the glass-house before being engraved or cut. Thus, at the expense of a couple of shillings, any comfortable chair may be converted into an excellent insulating support.

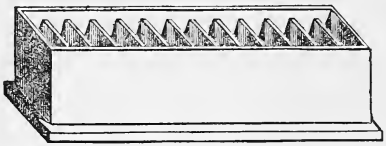
Fig. 19.



Galvanic electricity, or that excited by chemical action, is sometimes called in requisition. There are, however, many serious inconveniences attending its employment; and not the least of these is the bulky and unmanageable form of apparatus required for its excitation in a state of even moderate tension. On this account this form of electricity is now seldom employed, and in my own practice I confess I rarely use it; for the electricity of dynamic induction is so much easier excited, and, being the same in essence, has always been, so far as my own experience has extended, substituted for it. Whenever you wish to employ this form of electricity, you will find no apparatus more convenient for its excitation than the well-known

Cruikshank trough, which consists of a wooden trough, having double plates of copper and zinc fixed in, at short intervals from each other. These

Fig. 20.



plates need not be more than two inches square, and a trough containing three or four dozen pairs will be sufficient for all purposes. The best exciting fluid is very dilute hydrochloric acid, made by mixing one part of the acid with thirty of water. When the acidulated fluid is poured into the trough, you must take care that it does not rise to the top of the plates by about one-quarter of an inch. In using this apparatus, a piece of copper wire should be twisted at one end into a loose coil, and plunged in the first cell of the battery, another similar piece being immersed into the last cell. These wires become the conductors or *electrodes*, or, in other words, their free ends represent doors, out of which currents of the two electricities escape; and, by placing them in contact with the surface of the body, previously moistened, to make it as good a conductor as possible, the union of the two electric elements will

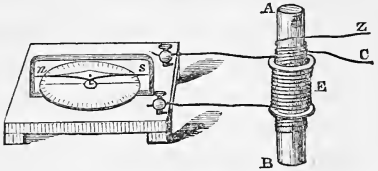
take place in the tissues they traverse. Bearing in mind the facts I announced to you in connexion with the course traversed by currents with the development of certain phenomena of nervous irritability and muscular contraction, you will at once see the importance of being able in an instant to ascertain the direction of the two currents when excited by the action of the acid on the zinc and copper plates. This you can at once discover by looking at the trough, and remarking that the positive current escapes from the end towards which all the zinc plates look, and the negative current from the other end.

The great drawback to the utility of this mode of exciting electricity is the trouble of getting the apparatus in proper order; the irregularity of the current in regard of strength, its tension and quantity rapidly sinking from the first moment of adding the acid; and, lastly, the damage inflicted by the latter when ejected from the trough, from too violent an effervescence, or from its being accidentally spilled.

The next mode of exciting electricity is of late discovery — one of the many contributions to physical science for which we are indebted to the talents of our illustrious countryman, Dr. Faraday. It furnishes us with large quantities of electricity of tolerably high tension, and possesses advantages for medical purposes which no other

mode of exciting electricity affords. To illustrate the mode of exciting electricity by induction, in the simplest manner, I will connect this piece of copper wire wound into a circular coil with the terminal screws of a galvanometer. I have here

Fig. 21.



a wooden cylinder, round which is wound a piece of insulated wire, so as to form thirty or forty convolutions, and will place this in the centre of the coil connected with the galvanometer. The needle of the instrument is now at rest; but observe what occurs the instant I connect the ends of the wire coiled on the wooden cylinder with the zinc and copper plates of a single galvanic battery. In an instant the needle darts off, as if acted upon by some tangential force; and, after several violent oscillations through a considerable arc, it slowly attains a state of rest, several de-

Fig. 21. A B, the wooden cylinder covered with wire, the ends of which, Z, C, are connected with the terminal plate of a battery. *n*, *s*, the magnetic needle of the galvanometer. E the circular wire coil connected with the wires of the galvanometer.

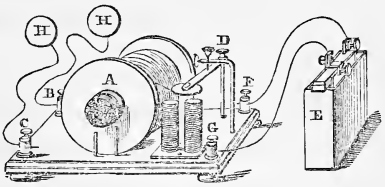
grees out of the magnetic meridian. Now, as the wire on the cylinder had no connexion whatever with that of the coil, it is obvious that the battery merely acted as an exciting agent in disturbing the normal electric equilibrium of the wire, causing the electricity to circulate in the form of current. This current, you will observe, is but of momentary duration, and is excited only at the instant that the battery current first traverses the conducting wire. But now, the needle being perfectly quiet, I will suddenly break contact with the battery, and once more the needle rushes out of the meridian line, and traverses a considerable arc, but in a direction opposed to that in which it travelled when connexion was in the first instance made with the battery. Like the former current, this is only of momentary duration. From this experiment we learn, that, when a current traverses a wire, it induces or excites another current in any conductor held parallel to it, a second being excited the instant the first current ceases to traverse the wire. These currents are respectively named primary and secondary, and are always opposed in direction, the primary current moving in an opposite direction to the battery or exciting current. If, instead of using a battery current as an exciting agent, I had plunged a magnet into the centre of the coil connected with the galvanometer, the electric equilibrium of the wire would

in like manner be disturbed, a primary current being induced on first introducing the magnet, and a secondary one on withdrawing it. It is obvious that if by any contrivance contact with the battery could in the first example be rapidly made and broken; or, in the second, the magnet be as quickly immersed and withdrawn, we should procure a rapid series of currents moving alternately in opposite directions; and on this is founded the construction of all the magneto-electric and electro-magnetic machines.

Numerous forms of electro-magnetic machines have been suggested for medical purposes; and it is really not a matter of any importance which you employ, provided care be taken to have the one you have chosen so arranged as to allow of a sufficiently copious development of electricity. As we have seen that in all such contrivances a small voltaic current furnishes the initial force, it is important to have this completely under command, and to be able to make and break contact with the inducing apparatus, with the utmost facility and rapidity. You may break contact with the battery, if you please, by means of a ratchet or cog-wheel; but this is often inconvenient, as it renders the services of an assistant necessary. On this account an automatic apparatus is always to be preferred. I believe I proposed the first of these several years ago, in the Annals of Philosophy; but this, as well

as all others I have seen, is much inferior to one constructed by an ingenious philosophical instrument-maker Mr. Neeves, of Broad Street, Holborn, and this is the only one I ever now employ. It possesses the advantage of simplicity, facility of employment, quantity and intensity of the induced electricity, together with the additional recommendation of low price.

Fig. 22.



This consists of a wooden bobbin, with a hollow axis. About thirty feet of thick insulated copper wire are wound on it, and over this about a thousand feet of very fine insulated copper wire, the ends of which are soldered to a couple of binding-screws fixed in the base of the instrument. The former is the coil in which the initial or *inducing* current is intended to circulate; the latter is the secondary coil, whose electricity is to

Fig. 22. A, the wooden bobbin, on which is wound the double coil of wires. B, C, the screws connected with the ends of the fine coil, with conductors affixed. D, the apparatus for breaking battery contact. E, single pair of plates (Smee's arrangement) connected with the screws, F, G. H, H, the conductors by which the induced currents are directed to any object.

be disturbed and thrown into motion, to form the *induced* current. One of the ends of the primary inner coil of thick wire is connected with the zinc plate of a simple battery; the other end of the wire surrounds a small horse-shoe of soft iron, and is then soldered to the lower end of a bent rod of brass, whose upper end carries a small screw furnished with a platinum point, which presses on a plate of the same metal fixed to a transverse bar of thin brass, having at the end suspended over the poles of the horseshoe, a disk of soft iron. When the fixed end of this bar is connected with the copper or silver plate of the little battery, the disk of iron is rapidly attracted by the ends of the horse-shoe, which acquire a powerful magnetic force. In an instant, the contact between the platinum wire and plate being broken, the current is arrested, and, the horse-shoe losing its magnetism, the electricity of the brass bar causes it to fly up and again bring the platinum point and plate in contact, when the same series of alternate attractions and repulsions occur. In this way you see the brass bar rapidly vibrate, and produce a loud humming musical sound, varying in pitch according to the amount and amplitude of the vibrations; and contemporaneously a rapidly succeeding series of induced currents traverse the coil of fine wire. If I now grasp in my hands a pair of brass cylinders connected with the ends of the fine coil, a series of

currents of high intensity, and rapidly succeeding each other, rush through the arms, producing a most painful and nearly intolerable sensation. You observe that a bundle of iron wires is placed in the hollow axis of the bobbin. The use of this is obvious enough; for these wires becoming a series of powerful temporary magnets add their inducing power to that of the initial current, and greatly increase the tension of the excited electricity. Indeed, by withdrawing the bundle of iron wire, you may diminish most materially the severity of the shocks produced by this instrument, and thus enable you very conveniently to adjust their force according to the case under treatment.

Sometimes the coils of wire are placed vertically, and then the exposed ends of the bundle of

Fig. 23.

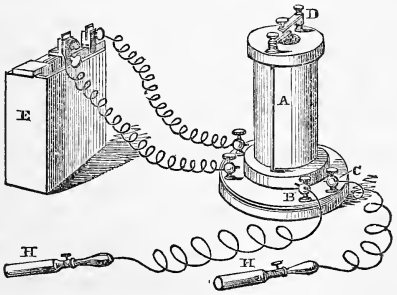


Fig. 23. The description of Fig. 22, equally applies to this: the analogous parts being marked with the same letters.

iron wire in the centre is made to attract the little disk of iron, and thus break contact. This form of apparatus is preferred by some.

If you reflect for a moment on the principles on which the construction of these very convenient arrangements is founded, you will at once see that you cannot obtain, by the aid of either of these machines, a series of positive or negative currents in a definite direction; that neither of the conducting-wires is capable of being regarded as negative and positive. This you can readily understand from the results of the experiment I showed you just now with the galvanometer. Each of the conducting-wires of this instrument conveys, alternately, currents in opposite directions. The wires, at the rate the bar is now vibrating, convey about 500 currents per minute, each being alternately negative and positive. To demonstrate the truth of this statement I have here on a glass plate a piece of paper moistened with a mixed solution of starch and iodide of potassium. I place on it the platinum extremities of the conducting-wires of the electro-magnetic apparatus; the currents pass, electrolytic action occurs, the iodine is severed from the potassium, and being set free, stains the starched paper. On examining the paper you will find the purple stain of iodide of amidine at both points where the platium wires touched the surface. Now, as the iodine is invariably liberated at the place where positive elec-

tricity enters the body containing it, we have a proof of the accuracy of the statement I made, that positive and negative electricity were alternately evolved at both wires. On this account, however useful this apparatus is when we want the mere stimulant action, the simple shock of the electric agent; yet it is likely to fail in certain forms of paralysis, in consequence of our not being able to transmit by its aid the positive current in the direction of the nervous ramifications.

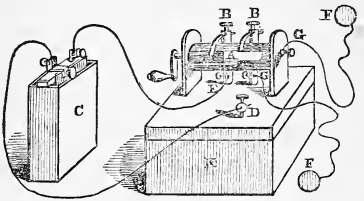
The more elegant and elaborate magneto-electric machine, especially the very effective and powerful one of Mr. Clark's construction, may of course be substituted for the electro-magnetic apparatus I have described. The advantages it presents of being always ready for use, and requiring no initial voltaic current to set it in action, are not, however, I think by any means sufficient to compensate for its expense, and the readiness with which it is disarranged, especially when in the hands of the uninitiated.

To render the electro-magnetic current available where it is required to be transmitted in a definite direction — where, indeed, we want the currents separated as we get them in the voltaic or galvanic battery, without the serious inconvenience attending the use of these pieces of apparatus — some modification of the electro-magnetic machine is required. After devoting some attention to the subject, I contrived the machine before you, which

answers the purpose most completely. It consists of the double coils of wire fixed in a box, on the lid of which is placed a wooden cylinder, capable of revolving between two uprights by means of a proper handle. This cylinder is furnished with two slips of brass fixed in the wood at each end, and connected with the metallic axes by which the cylinder is supported in the brass collars of the uprights. The slips of brass are placed so as to alternate with each other at either end of the cylinder. Two elastic brass springs, supported by pillars of that metal, press on the cylinder at either end. The ends of the thick wire of the coil concealed in the box are connected—one to the end of one of the supports of the cylinder, the other to a binding-screw fixed in the lid. The zinc and silver plates of a simple battery are then connected with this screw, and with the supports of one of the brass springs. On revolving the cylinder, contact with the battery is of course made or broken, according as the slip of brass or the wooden portion of the cylinder passes under the brass spring. You know that with each of such unions and ruptures of contact, an induced current circulates in the fine coil of wire in the box. The ends of this coil are soldered to the second upright, and the support of the second spring. The pieces of brass being properly arranged, it follows that one kind of current can alone traverse the

conducting-wires fixed to the supports connected with the fine coil. To prove this I will let these conductors, terminated as before with platinum ends, rest on the iodized paper. On turning the cylinder, the iodine is, as you see, set free at one end only. I know, therefore, that the positive electricity escapes by this wire, and the negative by the other. Hence by this instrument we have succeeded in obtaining separate currents, although we have lost the great convenience of the automatic movement of the other apparatus.

Fig. 24.



Let me now say one word respecting the agent evolved by these different pieces of apparatus. By all of them electricity is excited, and the terms of electricity, galvanism, and electro-magnetism really refer only to different conductions of the same agent.

Fig. 24. The single current electro-magnetic machine. A, the revolving cylinder, with slips of brass inlaid, on which the springs, B B, press. C, the battery, connected by wires with the screws D, E. F F, the conductors, connected with the screws G G, which are in communication with the fine coil in the box, K.

Thus by the common electrifying machine we obtain a small quantity of electricity in a state of high tension or elasticity, capable of effecting a discharge through very imperfect conductors. Electricity is obtained, on the contrary, from the voltaic or galvanic trough in a very different state, its quantity being large, but its tension or elasticity being so slight that it cannot effect a discharge through any but good conductors, a piece of tissue paper being sufficient to resist altogether the passage of a current capable of heating red-hot several feet of platinum wire. In the electro-magnetic machines electricity is afforded to us in moderate quantity, and in a state of tolerably high tension, still much inferior in this respect to that afforded by the electrifying machine. The currents alternate in direction in the double-current machine (Fig. 22), whilst they are in the same direction in the single-current apparatus (Fig. 24).

I purpose, next, to direct attention to the results which have followed the employment of the different modifications of electricity in the treatment of disease. In doing this I do not intend to occupy your time by a tedious reference to all that has been previously published on this subject, in this country and on the Continent. Such records are familiar to every physician, and within the reach of everybody who will take the trouble of referring to them. I am more anxious to avail

myself of this opportunity of presenting to the members of the College the results which have fallen under my own personal experience.

Electricity has been by no means fairly treated as a therapeutical agent; for it has either been exclusively referred to, when all other remedies have failed—in fact, often exclusively, or nearly so, in helpless cases—or its administration has been carelessly directed, and the mandate, "Let the patient be electrified," merely given, without reference to the manner, form, or mode of the remedy being for an instant taken into consideration.

Conscientiously convinced that the agent in question is a no less energetic than valuable remedy in the treatment of disease, I feel most anxious to press its employment upon the practical physician, and to urge him to have recourse to it as a rational but fallible remedy, and not to regard it as one capable of effecting impossibilities. I again say, I shall advance nothing but what has been repeatedly tested under my own observation, purposing to lay before you the results of many years' careful clinical experience in this matter, in the wards of Guy's Hospital; and hope to make out a strong case in favor of this too much neglected remedy.

In the autumn of 1836, the authorities of the hospital thought fit to set apart a room for the ad-

ministration of electricity. Clinical clerks were appointed to record the cases, and the whole was placed under my control, and remained in my hands during eight years; and when my other duties compelled me to give up this charge, my successor, Dr. Gull, has watched over it with great zeal and assiduity. In the case books of this department of our hospital is recorded a large mass of clinical experience on the subject before us—larger, I presume, than exists anywhere else; and from these records I propose to cull such matters as appear of the greatest interest and highest practical importance.

It must not be supposed that large and cumbrous pieces of apparatus, or energetic and powerful currents of electricity, are invariably required to develope very appreciable results, even on the human subject. The observations of Achard and of Humboldt, related in the previous Lecture, have taught us the contrary. From what I have seen I am fully convinced, that a feeble current, if kept up for a long time in certain forms of paralysis (care being taken that the positive fluid traverse the limb in the direction of the ramifications of the nerves), would prove the most important mode of applying this remedy with success. I was very sanguine that the current excited by a single pair of zinc and silver plates similar to those we employed to excite contraction in a frog, would be found of great value in practice. On submitting

this to the test of experience it was met by a difficulty which completely put an end to our hope of being able to keep up a current of low intensity for any length of time. Although I have had evidence sufficiently satisfactory to convince me of the efficacy of such a current, in forms of recent paralysis where, after the removal of the immediate cerebral lesion by treatment, the palsied muscles do not recover their power. The following case (which I give in the words of my friend, Mr. Hinton, of Hayes, at that time my very zealous pupil and clinical reporter), will alike illustrate the occasional efficacy of such a feeble current, and will illustrate the obstacle to which I have just alluded.

"CASE.—Thomas M——, aged 32 years, was admitted, Dec. 30, 1847, into No. 5, Naaman ward, with hemiplegia of the right side, under the care of Dr. Golding Bird. He is married, by trade a tanner, and has always enjoyed good health; habits temperate; no hereditary tendency discoverable. The following history was obtained: —On the 12th of this month he retired to bed in apparently good health, but during the night his wife was disturbed by his making a peculiar noise with his mouth; on obtaining a light, however, he appeared to be asleep, and when roused, said there was nothing the matter. Some incoherency of speech was noticed, but attributed to sleep. He

was restless during the remainder of the night, and in the morning it was discovered that the right side was completely paralysed, the speech very imperfect, and the face considerably drawn to the left side. He was attended by a medical practitioner; and the more alarming symptoms subsided under antiphlogistic treatment, the leg rapidly regaining power, so that when admitted he could walk tolerably. The following were his symptoms on admission:—Occasional pain over the forehead, with some degree of vertigo; no loss of memory; constant tendency to laugh when spoken to; paralysis of the right facial nerve; both pupils dilated, especially the left; both acting freely. The arm is perfectly motionless, but when he gapes, it rises involuntarily; the leg drags slightly; sensation is somewhat deficient over the upper extremity. The tongue turns to the paralysed side, and has a tolerably thick fur on that side only. Heart's action normal; pulse 60, full, laboring, firm; bowels regular; the urine acid, and remaining unaltered on the application of heat. The head is rather narrow and long, but the forehead is well formed.

"After the bowels had been well acted on, electricity was used daily in the form of sparks drawn from the spine, and he certainly improved; on the 8th of January the sulphate of zinc was ordered in grain doses, three times a day.

"Jan. 15th.—Feels much better; countenance

improved; twisting of face scarcely noticed; pupils equally dilated; tendency to laughing continues. He can now walk without a stick. Power of motion increases; he can partially throw out the arm, and in the morning can clasp the fingers a little: this power, however, is soon lost. He sleeps badly.

"From this date little alteration took place until the 18th, when Dr. Bird ordered the following plan to be adopted. Two blisters having been formed, one about the insertion of the deltoid, and the other above the posterior part of the wrist-joint, a zinc plate, the size of half-a-crown, with copper wire attached, was applied to the upper, and a silver plate to the lower. Over each plate, water dressing was applied, and above this, oiled silk (merely for the purpose of retaining the moisture), which was secured by strapping. The arm was then enveloped in a loose roller, through the folds of which the wires connected with the plates protruded, and on contact being made, the patient experienced a tingling sensation *at the silver plate alone.*

Fig. 25.

Fig. 25. Z, the zinc plate. A, the silver plate. When connected by the wire, the positive current will pass from the silver to the zinc plate, and down the arm in the direction of the arrow.

"19th.—About 3 A. M. he experienced severe pain in the arm, which soon wore off. Motion very much improved; the arm can be raised to a level with the shoulder, and power over the fingers is greatly increased. The patient was quite delighted at the sudden progress which he had made. Tingling sensation still experienced. The apparatus was taken off in the evening; the surface of the upper sore (zinc) was coated with a firm whitish matter, like lymph; nothing peculiar about the lower sore. The plates were again applied. For the next few nights he experienced severe pain and spasm of the muscles of the arm, but this did not last long. On the 20th and 21st, he thought that there was less motion, but on trial he could still lift the arm on a level with the shoulder. On the 22d, he lifted it above the level of the shoulder, and could clasp slightly. On the 23d, he could lift his arm on to his head. The slough forming on the zinc sore appears to increase in thickness. Before taking off the apparatus, I tried whether any current was passing, but failed in obtaining any decided effect on the galvanometer. With another patient, who was then in the house, by constantly breaking and reforming the current, the needle moved over an arc of 30°.

"29th.—The slough was found to be separating, and exuding a thin sanious pus. The apparatus was ordered to be discontinued, and a

bread poultice to be applied. A faint blush is all that remains of the sore above the wrist.

"31st.—The slough has separated, leaving a most perfect specimen of a healthy granulating sore.

"The sore began to heal rapidly, its healthy character continuing—the pus poured out being perfectly healthy. Power over the arm increases.

"He continued to improve up to Feb. 11th. The dose of zinc was then increased, and gradually reached seven grains three times a day; but for the next fortnight the power of motion, if anything, decreased. He again went to the electrifying room, and again he improved. The sore had now nearly disappeared, maintaining a healthy character, until nearly healed. The granulations then became rather flabby. On the 27th he was made an out-patient.

"As regards the employment of electricity, this appeared to be a favorable case. The patient had completely passed the dangerous period of reaction, and was perfectly free from all appearance of fever, and accordingly he was electrified, by drawing sparks from the affected limb, three times during the week. Some progress was made, and it then occurred to Dr. Bird that a continuous feeble current might prove more beneficial, and he determined to try the plates. To my mind the

result was most satisfactory for the time; and I think that greater progress was made during the few days that the apparatus was applied, than at any previous or subsequent period. We were not, however, prepared to see a large slough separate from the sore to which the zinc had been placed; and when the slough had separated, the use of the plates was discontinued."

We are often anxious to produce a persistent discharge from some part of the body, in cases where an issue or seton, or discharge from the moxa or actual cautery would be desirable. Now the knife for the issue, the needle for the seton, and the ignited tinder or red-hot iron for the moxa, all have their terrors for timid patients, and there is often the greatest unwillingness to induce patients to use such means. There are therefore considerable advantages in the use of a plan which, while it is perfectly competent to produce a copiously discharging sore, shall at the same time not excite the alarm of the most sensitive patient. Now the effect, noticed in the case just related, points out such a means. It was long ago observed by Humboldt, and afterwards by Grapengiessier, that when a simple galvanic arc was applied to a blistered surface, the part opposed to the most oxidisable metal was more irritated than that to which the negative plate was applied. But neither of these philosophers have noticed the effects arising from a continued

application of the plates. As I believe this *electric moxa*, as I have termed it, is often of very great value, I may be excused giving more minute directions for forming it. Order two small blisters, the size of a shilling, to be applied to any part of the body, one a few inches below the other: when the cuticle is thus raised by effused serum, snip it, and apply to the one from whence a permanent discharge is required a piece of zinc foil, and to the other a piece of silver; connect them by a copper wire, and cover them with a common water dressing and oiled silk. If the zinc plate be raised in a few hours, the surface of the skin will look white, as if rubbed over with nitrate of silver. In forty-eight hours a decided eschar will appear, which (still keeping on the plates) will begin to separate at the edges in four or five days. The plates may then be removed, and the surface where the silver was applied will be found to be completely healed. A common poultice may be applied to the part, and a healthy granulating sore, with well-defined edges, freely discharging pus, will be left. During the whole of this process, if the patient complains of pain at all, it will always be referred to the silver plate, where, in fact, the blister is rapidly healing, and generally not the slightest complaint will be made of the zinc plates, where the slough is as rapidly forming. A very interesting physiological phe-

nomenon is observed in making an issue by these means. If the plates be applied to a limb, and on different places, contraction of the subjacent muscles will always be observed most severe when the patient is in the act of falling to sleep; and in a few cases these sensations have been sufficiently annoying to induce the patient to untwist the wires fixed to the plate, when, by interrupting the current, these feelings ceased. But if the plates were applied to opposite sides of the body, as when on the chest to different sides of the mesial line, no contractions whatever occurred. This admits of explanation by a reference to the fact of the nerves not crossing the middle line of the body. My friend Dr. Gull once met with a case in which the application of these plates, with the view of forming a moxa, produced intolerable distress. The patient was the subject of spinal disease, and this probably accounted for the extreme sensibility of the cutaneous nerves.

I have now repeatedly used this mode of exciting a puriginous sore on different parts of the body, both in hospital and private practice, and it has never in any instance failed; I strongly recommend it to your notice, where it is important to avoid the use of means more alarming to the patient. I certainly know of no other plan by which an equally effective discharge can be ob-

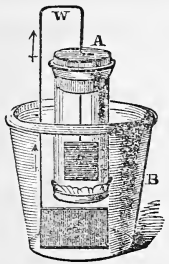
tained, except by the use of the moxa or actual cautery.

As scientific and philosophic physicians, we must, however, go a step further, and inquire into the rationale of this process: after some little investigation, I traced it, as indeed was to be expected, to the principles laid down in my second lecture, when endeavoring to show how small an amount of electric force was sufficient to tear asunder the elements of many compounds.

In fact, the saline ingredients of the fluid effused on the surfaces of the blisters are decomposed, the sodium of the common salt being set free at the silver surfaces, which, by oxidation, of course, rapidly become soda: the chlorine is evolved at the zinc surface, forming chloride of zinc. An electric current is then traversing from the zinc through the interposed tissues to the silver, and back again to the zinc, and its actual existence may be demonstrated by separating the wires belonging to the plates and connecting them with a galvanometer. I believe, therefore, the sore is really formed by the escharotic action of the chloride of zinc thus produced; and the reason why the patient feels none of the intense pain so characteristic of the caustic energy of the zinc salt, is found in its acting in infinitely small portions at a time upon the skin,—indeed, in what may be correctly enough termed a nascent

state. To prove this is not mere hypothesis, I have placed on the table a vessel containing a weak solution of common salt, having a tube closed at the bottom with an animal membrane, and also containing salt and water immersed therein: a piece of silver was, some hours ago, placed in the outer vessel, and a piece of zinc connected with it, in the tube. The two pieces of metal are thus placed under conditions nearly parallel, if not identical, to those in which they are, when used to form the moxa. If the fluid in the inner tube be tested by adding to one portion of it ferrocyanide of potassium, and to another some ammonia, the occurrence of a white precipitate in either case will at once attest the presence of chloride of zinc in solution.

Fig. 26.



Conversing on this subject with my friend and colleague, Dr. Babington, whose profound erudition and high scientific attainments are familiar

Fig. 26. A, a glass tube closed at its lower extremity with a piece of bladder, filled with a weak solution of common salt, and immersed in a glass vessel, B, also filled with the same solution; a plate of zinc, Z, is immersed in the tube, and a piece of silver, connected with it by a conducting wire, W, is placed in the vessel B: the direction of the positive current thus excited is shown by the arrows. In a short time A will be found to contain chloride of zinc, and the fluid in B will be strongly alkaline from the presence of soda.

to us all, he mentioned to me some analogous experiments, performed by him as far back as 1827, on the action of weak currents on muscular flesh; he also kindly placed in my hands the notes he had preserved of his researches. Of his many ingenious experiments, the following bears most on the subject of my electric moxa:—The Doctor took two slices of muscular flesh, placed one between two plates of glass, the other between plates of copper and zinc, binding them together with wire. In the course of a few days, the weather being warm, the flesh between the glasses began to putrefy, and soon afterwards was full of maggots, whilst that between the metallic plates remained free from putrescency. A remarkable change had, however, occurred, for, on taking off the plates, the side opposite to the zinc plate was hard, as if it had been artificially dried, whilst that opposed to the copper had become covered with a transparent substance resembling jelly. In fact, the result of the experiment evidently was, that the chloride of sodium existing in the flesh had become decomposed; the zinc had been acted on, and a dry hard compound of chloride of zinc and albumen formed on one side of the piece, whilst the soda set free on the other side had contrived with proteine elements to constitute an albuminate of soda in the form of a semi-gelatinous mass. This experiment on dead mat-

ter, compared with my own on the living body, affords a beautiful illustration of the wonderful influence of life in modifying chemical action. In the dead flesh mere chemical changes occurred: in the living tissue the principle of life interfered, on the one hand, in resisting the solvent influences of the soda set free at the silver surface, whilst that same principle, from the influence of the irritation of the chloride of zinc formed at the zinc surface, excited inflammation, and, by thus setting up a barrier against the further progress of the chemical action, cut off from the system the skin acted on by the acrid salt, and allowed its separation in the form of a slough.

The fact of the sore of a blister readily healing under the silver plate, whilst under the zinc, of a destructive action being noticed, pointed out two other applications of these plates, which may possibly lead ultimately to important results. As, however, I have not directed much attention to this, I shall content myself with quoting the following remarks of Mr. Hinton, who interested himself much with it.

"On observing that the blister upon which the negative plate was placed healed so rapidly, Dr. Bird suggested its application to old indolent ulcers, and, accordingly, when I became dresser for Mr. Bransby Cooper, it was several times put to the test, and with varied results, but on the whole

satisfactory. The cases in which it seemed to produce an extraordinary effect were those of tertiary sores; one of these cases had previously resisted all kinds of treatment. It is in these cases, I imagine, that it acts as an alterative, setting up a fresh action. It was also tried in a case in Stephen ward: here the character of the ulcer was very much altered; it assumed a remarkably congested appearance, and the discharge became sanguinolent. Yet even in this case (in my opinion), the most unfavorable that I witnessed, the size of the ulcer diminished, and cicatrization commenced at the lower part.

"Seeing that the formation of the slough depended on the action of the chloride of zinc, and knowing how exquisitely painful the common application of this remedy proves, I suggested to Mr. Cooper that its application might be successful in destroying small scirrhous masses, where, from various circumstances, the surgeon does not feel justified in using the knife. This was put to the test in a case of open scirrhous breast in Dorcas ward; in this case there was a large, deep, irregularly excavated sore, with hardened base, and often excessively tender. After the slough had separated, the negative plate was applied, and in some points cicatrization commenced —the great tenderness was much relieved. From the great irregularity of the surface of the sore,

it was difficult to apply it very effectually, yet the hardness at the base of the sore was materially lessened.

"I may state here, that in subsequent trials it was found that, in forming a slough, one blister, placed where the slough was to be formed, in general proved sufficient, providing the surface of the skin to which the silver plate was applied were previously bathed with a little salt and water, so as to make it a good conductor."

It is rather remarkable that neither Grapengiessier nor Dr. Harris, an American physician, who have employed these single plates, have alluded to the production of a puriginous sore under the zinc plate. This is the more unintelligible, as the latter gentleman evidently paid much attention to the subject, and pointed out the necessity of cleaning and replacing the zinc plate every few days.

[I am indebted to Mr. Spencer Wells, surgeon R. N., for some interesting information in connexion with the efficiency of these plates. The extract from this gentleman's letter to me, which is inserted in the Appendix,* will, I think, be read with much interest.]

* Appendix A.

LECTURE V.

Action of Electricity on Contractile Tissues.—Application of Electricity to excite Uterine Contractions.—Dr. Radford's Views.—Excitation of Uterine Action de novo—In flooding after Abortion—In Paralysis of the Bladder—Incontinence of Urine.—Treatment of Paralysis.—Different Forms of.—Dropped Hands of Painters.—Rheumatic paralysis.—Paralysis of the Portio dura.—Paralysis from Local Injury.—Hysterical Paralysis.—Aphonia in Hysterical Girls.—Paralysis from Anæmia and Nervous Exhaustion.—Paralysis from Cerebral or Spinal Structural Lesions.—Electricity as a Stimulant to the Absorbents—In Rheumatic Effusions—In Tonsillitis.—Application of, in Neuralgia—In Narcotic Poisoning—in Drowning.—Local Anæsthesia.—Treatment of Chorea and allied Affections by Electricity.—Analysis of the Cases.—Rationale of the action of Electricity.—Treatment of Amenorrhœa.—General rules for.—Conclusion.

We have seen that electricity, under all its modifications, is a most energetic agent in exciting contractions of muscular fibre. Indeed, we have, in several instances, actually used the irritable fibres of the muscles of a frog's leg as a positive test of the existence of an electric current. This susceptibility to the stimulus of electricity is not limited to real muscular tissue, but is equally participated in by those white contractile tissues, which by some physiologists are hardly regarded as belonging to the class of true muscles. I allude

particularly to the muscular coats of arteries, intestines, and bronchial tubes, as well as the structure of the uterus. Dr. J. C. B. Williams has actually demonstrated the contractibility of a bronchus under the influence of a current of voltaic electricity. The experiment already related, in which the current of a single pair of plates passing from the mouth to the anus of an ox, recently killed, excited the peristaltic motion of the intestines and induced defecation, sufficiently proves the susceptibility of the muscular structure of the intestines to the stimulus of electricity. Indeed, I have repeatedly had my attention directed by patients under electric treatment for various diseases to the influence of this agent as a purgative. A gentleman who, some years ago, was under my care for paraplegia, accidentally noticed that the passage of a current from the electro-magnetic machine across the abdomen, in the direction of the transverse colon, almost always induced a desire to empty the bowels, and he has ever since appealed to this remedy as a purgative. He assures me it seldom fails.

But there is another special application of electricity which I dare not pass over in silence, although I cannot from my own personal experience say anything about it, as the cases to which it is referable fall under the province of the accoucheur. Few cases are more appalling than those of flood-

ing during labor; none can occur in which the woman's life is more immediately dependent upon the moral courage, promptitude, and skill of the accoucheur. Among other causes inducing this hemorrhage, an atonic state of the uterus is the most dangerous. In such cases, as well as in many forms of placenta prævia, where the blood is fast gushing from the uterus, and the woman's powers as rapidly sinking, a distinguished provincial obstetric physician, Dr. Radford, of Manchester, has advocated the employment of induced electro-magnetic currents to induce energetic contraction of the uterus. He has further suggested its application for the purpose of originating uterine contractions *de novo* in cases where it is important to induce premature labor, as well as in certain cases of menorrhagia in the unimpregnated state, where the uterus is found large, atonic and flaccid.

Dr. Radford applies the electricity of the electro-magnetic machine, one of the conductors being passed over the abdomen, especially in the neighborhood of the fundus uteri, the other being introduced into the vagina so as to be brought into contact with the os uteri. This vaginal conductor is made of stout brass wire, covered with a non-conducting material, as caoutchouc, and terminated by a ball of silver, by which the electric current is conveyed to the uterus.

This practice, so far as its application to the

gravid uterus is concerned, has received the sanction of my colleague, Dr. Lever, whose high obstetric experience invests his opinion with great weight. This gentleman has availed himself of the use of the electric current in cases where atony of the uterus existed, and where, from threatening exhaustion, independent of danger of hemorrhage, immediate delivery was important. An excellent illustration of this occurred under the notice of a talented and excellent practitioner, a former pupil of mine, Mr. Cleveland (now of Aldersgate Street), the notes of which I will read to you:—

"I was requested to see M. C., æt. 39, in her sixteenth confinement, on Friday morning, June 6th, 1845.

"On my arrival at the house, I learned that her previous labors had been tolerably good; with two or three exceptions, when they had been considerably protracted from want of pains; she stated that her health had always been delicate, and for the last few weeks she had had a troublesome cough, attended with copious expectoration, emaciation, and occasional night sweats,—symptoms that induced me to suspect she had phthisis, although subsequently this diagnosis was not confirmed by a physical examination of the chest.

"On the Sunday evening prior to my visiting her, she was attacked with the premonitory symptoms of labor, soon succeeded by regular and fre-

quent pains, which, on the following morning, abated, but never entirely left her until the Wednesday night, when the liquor amnii was discharged.

"At 1 A. M. on the Friday, the pains returned with considerable vigor, but did not last above an hour, and at 6 A. M. they were again renewed for a short time. It was about four hours after this period that I found Mr. T., a medical practitioner in the neighborhood, with the patient. He had administered a dose of the tincture of ergot, and also some spirit and water; but these measures were followed by only a few slight and ineffectual pains.

"Having ascertained by an examination per vaginam that there was no obstacle to the termination of the case but a want of contraction of the uterus, and believing it desirable that, as there were some rather alarming symptons of exhaustion manifested, no time should be lost, I was soon provided with an efficient electro-galvanic apparatus, and resolved on a trial of electricity.

"I was gratified in finding, after a few applications of the remedy externally and obliquely across the anterior surface of the uterus, alternately changing the position of the conducting wires, that a very decided effect was produced. Regular, strong, and frequent pains came on, and, in the course of a quarter of an hour, a living

male child and placenta were expelled, attended with the least degree of hemorrhage I ever witnessed.

"The uterus was immediately firmly and permanently contracted, and, with the exception of a slight soreness across the abdomen, the patient expressed herself as feeling quite comfortable. She recovered but slowly, on account of the general debility induced by the affection of the chest, but there was not a single bad symptom connected with the uterus subsequently developed."

I am quite aware that Dr. Simpson, of Edinburgh, has expressed his opinion of the inefficacy of the electric current in such cases, and had almost denied its exercising any influence over the uterus. I confess I cannot for one moment admit the validity of his opinion when opposed by the facts of Dr. Radford, Dr. Lever, and others; but would endeavor to show the mode in which these opposite statements appear to admit of reconciliation. This is founded on the opposite effects of currents, according as they follow the cause of the centripetal or centrifugal nerves. Now in the magneto-electric coil, in which currents are excited by repeatedly breaking contact by a vibrating bar, the apparatus, whose construction I explained at my last lecture (Fig. 22), we have, as I have already shown, two currents moving in

opposite directions, to each of which the patient who is the subject of experiment becomes submitted. Now these currents are of unequal strength, and if the most energetic, that on breaking contact, be passed in the direction of the *vis nervosa*, it will produce painful contractions, which the moment it passes in the opposite direction will become relaxed. For, as I have proved to you, an inverse current tends to produce paralysis, and a direct current contraction. Hence I should urge the accoucheur not to employ the apparatus in which both these currents traverse the patient, but simply the one I have described to you, as the single-current machine, and which is now on the table before me (Fig. 24). In using this, I would suggest the positive conductor to be placed over the lumbo-sacral region, and the other be carried only over the abdominal surface with a gentle friction. In this way powerful uterine contractions will be easily excited. You will never find any difficulty in getting this apparatus to act efficiently, as it possesses the great advantage of dispensing with the use of mercury, which has generally been used in these single-current machines.

It has occurred to me more than once to notice the occurrence of abortion as the result of the transition of electric shocks through the pelvis

in cases of amenorrhœa, where the patient has for intelligible reasons criminally concealed her pregnancy. I have, therefore, not the slightest doubt that the stimulus of electricity, more particularly in the form of the magneto-electric current, is in some cases quite competent to set up uterine contractions. Still it must not be considered as invariably successful, for it has occurred to my colleague, Dr. Oldham, to observe and regret its failure in a case under his care in the hospital, in which he was most anxious to bring an abortion in a patient three months advanced in pregnancy, in whom delivery at the full time was utterly impracticable from the contraction and remarkable adhesion of the vaginal walls. Although applied on two occasions for upwards of a quarter of an hour, the only observed effect was violent contraction of the abdominal muscles, and some hardening of the uterine tumor, followed by a slight discharge of mucus tinged with blood. Having felt a good deal of interest in this matter, I have been at some pains to collect information from those who have used the electro-magnetic current as an excitor of uterine action. The result at which I have arrived is that this agent, like ergot of rye, and perhaps other ecbolic remedies, generally fails to develope uterine contractions *de novo;* but that having once been excited, they are always and almost invariably rendered more energetic, and even when they

have ceased for awhile, they are readily again actively set up by the application of the current. Hence, although I believe it will generally fail to induce premature labor, it will as generally succeed in stimulating the uterus to rigorous contractions after labor has actually commenced.*

Mr. Wilson, of Runcorn, successfully employed the electro-magnetic current in a very distressing case of flooding after an abortion at two months, in which the hemorrhage kept up in spite of every plan of treatment had failed. In this case, the ergot of rye was quite inactive, and plugging the vagina was useless, for the hemorrhage went on behind the plug, and ultimately expelled it. The current from the electro-magnetic apparatus produced firm contraction of the uterus, and arrested the discharge, apparently just in time to save the patient's life, as she was completely blanched by the loss of blood, and to all appearance was rapidly sinking from exhaustion.

Dr. Radford has successfully employed the electro-magnetic current to restore tone to the bladder, when that organ has been paralysed by previous over-distension during labor. It is well known

* I would beg to direct the attention of the reader to a very interesting communication in the Appendix, from a very careful and talented practitioner, Mr. Dempsey, who has directed much attention to this very important subject. (Appendix B.)

that when the bladder has been long distended with urine, a want of power to expel its contents often results, and this will often continue for some weeks, so as to render the daily use of the catheter necessary. In a case of this kind, following protracted labor, Dr. Radford passed a current from the electro-magnetic machine over the region of the bladder, with the almost immediate result of restoring that organ to the dominion of the will. In more than one case of want of power in emptying the bladder in hysterical girls, I have succeeded in curing this annoying symptom by passing a pretty strong current from the sacrum to the pubes. My own impression has been, however, that the pain of the current and dread of its repetition have constituted the real elements of success in these cases.

While on this subject I may allude to that very distressing incontinence of urine, not uncommon in delicate irritable children. This occurrence is most frequent at night, and is often very unmanageable. I have repeatedly applied the electro-magnetic current through the pelvis in cases of this kind, but I am sorry to say without any satisfactory results. A celebrated German physiologist, Froriep, has apparently been more successful, but he applied the current in a different manner. His plan consists in placing one conductor over the pubes and connecting the other with a

wire introduced into the bladder through a caoutchouc catheter. By this mode of introducing the electricity really into the bladder, Froriep states that he generally succeeded in curing his little patients.

In connexion with the therapeutical indication fulfilled by electricity of stimulating to contraction the muscular uterine structures, I propose next to direct your attention to the influence of this agent in the treatment of certain forms of paralysis. Indeed, no class of affections has been more frequently submitted to the agency of electricity than cases of paralysis of some part of the body, and in none have more triumphant success and more bitter disappointment followed its use.

Paralysis is so general a term, indicating so vast a variety of pathological conditions, that no opinion whatever can be given of the utility of the agent in question without being more precise in our definitions. One general remark, however, I may venture to make; that under no *circumstances whatever, have I ever seen any of the modifications of electricity of use in the treatment of paralysis attended with permanent contractions,* — a condition so frequently observed in the upper extremities. Indeed, so far from sanctioning the use of electricity in any of its forms in such cases, I feel convinced that it may even do mischief,

and hence on no account ever venture to employ it. As a general rule, I would especially guard the practitioner against using this remedy in any form of paralysis, where a source of permanent irritation exists in the brain or spine.

Practically, I would divide the forms of palsy presented to us for treatment into the following:—

1. Cases of paralysis from the poison of lead.
2. " rheumatic paralysis confined to the limbs.
3. " paralysis limited to portio dura.
4. " following local injury to a limb.
5. " hysterical.
6. " anæmic.
7. " dependent upon persistent cerebro-spinal lesion.
8. " local anæsthesia.

I now propose to consider *seriatim* the result of the use of electricity, in its various forms, in these different varieties of paralysis: and first of cases of dropped hands, as

Paralysis from lead.

Of eleven, notes have been preserved.

5 were cured.
4 " improved.
2 " not relieved.

Of these cases, 7 were traced to the patient's trade as a painter.
" 2 to sleeping in a freshly-painted room.
" 1 handling types as a compositor.
" 1 washing bottles with shot.

The following three cases will sufficiently illustrate the results of our trials in this affection:—

R. G., aged 19, admitted into Guy's Hospital July 12, 1837. He had been employed as a compositor during the last five years, and consequently engaged constantly in handling printer's types, in which lead enters as a prominent ingredient. His health up to the three preceding weeks had been excellent; at that period he first noticed a tremulous state of both hands, and shortly afterwards suffered from a severe attack of colic. At the time of admission he had paralysis of motion of both hands, chiefly confined to the extensor muscles: his general health was extremely deranged, and, from debility, he had extreme difficulty in walking. From the medical treatment employed, he became considerably improved; but not regaining power over his hands, he was sent to the electrical room on September 2: at that time he was completely amaurotic, this state

having gradually come on during the past year; and he had rather more power over the left arm than the right: sensation was tolerably perfect.

Sept. 2.—Sparks from the cervical and dorsal regions of the spine thrice a week. The papular eruption was produced with difficulty. He continued this treatment, with marked improvement, for some time; when, from an attack of bronchitis, he was confined to his bed.

Nov. 8.—Resumed the electrical treatment.

27.—Gradually acquiring more power over the paralysed muscles; and his pupils, previously nearly insensible to light, now contract and dilate readily, although he remains completely blind.

Jan. 12.—Paralysis completely cured; the amaurosis remains unrelieved.

C. B., aged 29, by trade a cooper, whilst at work, ten days before, was seized with a sudden feeling of loss of power in the right wrist and hand, which he attributed to his having been previously engaged in mixing white paint. On admission into the hospital, in August, 1840, the paralysis of motion of the extensors of the affected hand was complete: general health tolerably good. Ol. Ricini p. r. n., Sulph. precip. ʒi., t. d. Weak shocks down the arm, from the spinous processes of the cervical vertebræ to the fingers.

Sept. 11.—Has rapidly improved, and is now able to resume his work.

In cases of the dropped hands of painters, the conditions before mentioned being borne in mind, the electric sparks drawn from the region of the cervical and dorsal vertebræ are generally efficacious in at least aiding, if not effecting, a recovery. I have generally, also, directed them to be drawn from the paralysed parts; and, in recent cases, small shocks transmitted along the course of the affected nerves, have considerably accelerated convalescence: but in chronic cases I have repeatedly seen a cure effected by drawing sparks from the spine, on alternate days, for weeks, after shocks had been passed along the paralysed parts in vain. The following is a case of this kind.

W. C., aged 36, a plumber, admitted November 26, 1840, first noticed, three years before, a numbness of the right hand, which terminated in total paralysis of the extensor muscles. A year ago the left wrist became similarly affected, and he is now unable to raise either hand.

Nov. 26.—Sulph. precip. ʒi. t. d. Shocks down the arms on alternate days.

Dec. 16.—No improvement. He has no more power over his wrists than on admission. I directed sparks to be taken from the spine, thrice a week, for six or eight minutes.

Jan. 2.—Has gained power daily, and soon after this date was able to resume his work.

Rheumatic paralysis has been repeatedly treated by electricity, and notes of ten patients are pre-

served; of these, the youngest was 15, the eldest 50 years old.

Of these, 5 were paraplegic, limited to both legs,
1 " " hands,
3 limited to the right arm,
1 " right leg.

Of these, 5 cured,
3 relieved,
2 unrelieved.

Under the term rheumatic paralysis, I would include all cases in which the palsy followed the sudden application of cold, independently of any evidence of central spinal lesion. Such cases are common enough; they are sometimes attended with peripheral pains of a rheumatic character, and even occasionally with redness and tumefaction of the joints, which, however, are always evanescent. The line of demarcation between rheumatism and some of these forms of eccentric paralysis is very ill defined, and indeed, lends considerable support to the idea of a close connexion between rheumatism and some lesion of functions over which the true spinal system presides.

R. E., admitted Sept. 27th, under the care of Dr. Addison. It appeared that ten months previously, whilst on board a trading vessel off the coast of Africa, he became the subject of fever, for which cold affusion was copiously used; and to this he attributes the paralysis of the right

forearm and both hands, which appeared when convalescing from the disease. On admission, he was quite unable to move the paralysed limbs: his general health appeared excellent.

Sept. 27th.—Sparks thrice a week, from the spine and paralysed muscles.

Nov. 14th.—He has improved daily; and being now in possession of full power over the previously paralysed limbs, he was this day presented cured.

J. Y., aged 15, admitted into the hospital in the middle of January, 1837. Stated that sixteen months back he suffered from pain and swelling at the upper part of the neck: this was followed, in two months, by loss of power over the right arm; for which he continued under treatment during nine months without deriving any benefit, so far as power over the paralysed limb was concerned. It was then determined to try the effects of electricity; and in the middle of August twelve shocks were ordered to be passed from the region of the cervical vertebræ to the fingers of the right hand, daily.

Oct. 8th.—Has gradually improved, and has now considerable power over the affected limb.

20th.—Recovered completely the power of moving the arm; and was discharged, cured.

W. E., aged 30. This man had been employed in loading and unloading cargoes of coasting-

vessels at one of the wharfs; and a few weeks ago, whilst unpacking salmon, the cold water from the melting ice burst from one of the packages and drenched him completely. He took no notice of this; but on the following day the little finger of his right hand became numb: this gradually increased; and in a week he lost all power over both hands, sensation remaining unaffected.

Oct. 19th, 1840.—Sparks from the spine and the affected hands.

Under this treatment he rapidly improved; and after attending a few times, he became so much improved as to be enabled to return to his work.

The following case, recently under my care at Guy's Hospital, is a good illustration of rheumatic paraplegia thus treated; I give it in the words of my clinical reporter, Mr. Hinton.

J. R., æt. 58, laborer, married, comes from the Hundreds of Kent; his work consists chiefly in cleaning out ditches, &c.: in his younger days he lived freely, but for many years past he has led a temperate and regular life; general health pretty good; he has had ague many years ago, and several fevers, doubtless of an intermittent character, as he has lived in the Hundreds for nearly forty years.

To his knowledge none of his relations were ever affected with paralysis; ten of his children have died, and several of them apparently with

some phthisical affection. He has always noticed that his feet perspired very freely. In the latter part of the month of August last, he worked for three successive days in a ditch; during the whole of which he was knee deep in a running stream, and from this time all signs of perspiration about the feet disappeared, and, to use his own expression, "he found it strike to his limbs." He soon perceived that he was gradually losing the power of motion in the lower extremities, chiefly the right, and his feet always felt cold. His general health, however, has not suffered.

He says that his legs feel very heavy, and he compares it to having a great weight attached to each foot. The flexor tendons of the knee joint are somewhat tense, and he moves with great difficulty. There is slight loss of sensation, and a feeling of numbness. Urine is clear, of natural color, unaltered by heat: he passes about Oijss. in 24 hours; sp. gr. 1011.

Treatment.—Balneum tepidum. H. Sennæ p. r. n. Middle diet.

Jan. 2d, 1847.—Since the bath he has felt easier on the whole, and can move the lower extremities more freely. He says his legs feel "all of a work." General health continues good.—Ictus elect. è spin. dors. ad pedes ter in hebdom.

7th.—Continues pretty well, and finds his legs

much lighter; he moves more freely, and has perfect sensation; the feeling of numbness much diminished.

13th.—Continues to progress favorably; he now walks with a tolerably firm step without support of any kind; the legs are comparatively light. The right leg is decidedly the weaker. He feels the shock during the night.

20th.—Walks with tolerable freedom; occasional indecision of gait and power of motion: varies somewhat from day to day; general health continues good.

29th.—The paralysis appears cured: he walks freely; occasionally the right leg drags a little, and at times he feels it heavier than at others.

From this date he continued to improve, and was presented on the 9th February.

Paralysis of the portio dura is a not unfrequent affection, and probably bears considerable relation to the rheumatic paralysis which has just occupied our attention. It is unnecessary for me to allude to the importance of not committing the serious error of confounding this disease with paralysis depending upon cerebral lesion. It is impossible that any I have now the honor of addressing could ever fall into such a fearful error. Yet I dare say it has fallen to the lot of many of my auditors to be called to cases of this kind after the patient has been bled, cupped, blistered, mercurial-

ized, and his health and constitutional power shattered by such unnecessary treatment,—a treatment for which the most profound ignorance hardly affords an excuse. The history of the cases is sufficiently intelligible. A person previously in health exposes one side of the face to a little draught of air; as by sleeping near a window having a broken pane, or travelling in a railway carriage with a half open window. The result of this is more or less pain and stiffness in the side of the face, followed soon by paralysis of the facial nerve; the non-affected side being exceedingly distorted from the antagonist muscles becoming palsied. Sensation is never influenced, the affection being strictly and exclusively limited to the seventh pair of nerves. When consulted early in the affection there may be some evidence of inflammatory irritation in the course of the *pes anserinus* and its branches, demanding appropriate treatment. Very soon, however, this irritation subsides, and, as is well known, the patient, if left alone, generally with sufficient time recovers. Still, however, the convalescence involves much time, and in many instances, months elapse ere the symmetry of the face is recovered. In such cases the stimulus of electricity remarkably aids the cure: I say the *stimulus* of electricity, because in such cases it appears pretty certain that the agent in question acts merely as a local excitant, stimu-

lating the paralysed muscular fibres, and arousing their normal irritability, and once more placing them under the dominion of the will.

In these cases it scarcely matters what form of electricity is applied, so long as it is sufficiently effective to induce contraction of the paralysed muscles under its influence: weak shocks from a charged jar, the passage of a series of currents from an electro-magnetic machine, or the direct irritation produced by drawing a series of sparks from the cheek (when the patient is insulated and connected with the prime conductor of an electrical machine), seem to answer equally well. It is unnecessary for me to trouble you with any elaborate history of patients thus treated: a brief glance at two or three will be sufficient as an illustration of the subject.

A barrister, in large and influential practice, became the subject of paralysis of the portio dura on the left side, from exposing the cheek to a current of air from a broken window in a crowded court. He applied to me in a week or two afterwards, the paralysis continuing, and the distortion of the face hideous. As his general health was excellent, I ordered him to apply the currents of an electro-magnetic machine to the paralysed cheek for a few minutes daily; this was done for him by his servant, and in a fortnight all distortion vanished.

A young gentleman, sixteen years of age, became paralysed from the influence of a draught of cold air on his cheek while asleep. I saw him two or three days afterwards: there was no local tenderness in the course of the portio dura, but the distortion was extreme. I requested his father, himself a zealous cultivator of physical science, to place him upon an insulated chair, and, connecting him with the electrical machine, to draw sparks from the affected side; this was regularly done daily, and he rapidly recovered.

An instance lately occurred to me in the person of a clergyman, who had suffered from paralysis of the seventh pair of nerves a dozen years previously, and the paralysis had never completely disappeared; the face when I saw him was not symmetrical, the saliva often flowed from one corner of the mouth, and his intonation was impaired. He set sedulously to work with the electro-magnetic current, and I saw him some months afterwards perfectly restored.

Very lately I was called to a gentleman in Camberwell, whom I found in bed with a shorn scalp, and who had been under the influence of vigorous measures, as bleeding, cupping, blisters, and mercury, for what was presumed to be an apoplectic clot in the right side of his brain. He was rather worse than better for his treatment, and it turned out that he had walked to the city in an intensely

hot day, and sat down to his desk with his left cheek exposed to a current of cold air rushing through the broken window of his counting-house. Pain and stiffness came on, and when he awoke next morning his left cheek was palsied. It was evidently a sufficiently obvious case of paralysis of the portio dura; and after getting up his health, this patient, who had often dabbled in electricity, undertook his own treatment, and by drawing electric sparks from his cheek for nearly half an hour each day, he completely recovered. In this, as in other cases, I may remark the treatment at first appears remarkably successful, and the patient is often disappointed that he does not continue to progress as rapidly as he had hoped. Hence, it is very important to bespeak his patient persistence in the treatment for some weeks, before commencing the use of electricity.

In paralysis following local injury, the aid afforded by electricity depends upon the nature of the injury inflicted. If a blow, or other applied violence, has been sufficient to injure the structure of a nerve, no benefit can accrue, or, indeed, can be expected, from the use of electricity. But if, on the other hand, the paralysis has been merely the result of concussion of the nerves, &c.,—of some pressure which, although severe, did not disorganize the nervous fibres,—the remedy in question is often of service. In such cases I would ad-

vise the application of electro-magnetism from the *single-current machine* (described in my last lecture) to the paralysed limb, taking care to transmit it in the course of the *vis nervosa*, or, in other words, in the direction of the nervous ramifications. I think I have seen benefit thus obtained in the weak and feeble state of a limb following forcible reductions of a dislocation; as of the head of the humerus into the axilla.

In hysterical paralysis, I feel a great difficulty in expressing an opinion regarding the remedial influence of electricity, in consequence of the nearly impracticable task of distinguishing between the mere simulation, and the reality, of existing paralysis in hysterical women. It is really difficult to believe, that girls and women, whose very means of living decently, much less the possession of the comforts of life, depend upon their being enabled to exert themselves, should simulate paralysis; and yet we know that such is too frequently the case. The morbid state of mind which predisposes to such impostures presents a curious enigma for solution. Admitting the existence of such cases of deception and imposture, we too often run the risk of becoming uncharitable, and to consider many forms of functional paralysis as purely simulative. It is not for me to enter into the interesting problems of the vagaries of such cases: I will content

myself with pointing out the high importance of the electric shock, or uninterrupted current of an electro-magnetic machine, in such cases. If the patient simulates paralysis (and, when she does so, it much more usually is in the form of rigidity of a limb than any other) she can seldom resist the pain and surprise of the shock, and the previously rigid limb will generally instantly move. On the other hand, in hysterical paralysis, where the affection, however excited at first, is now uninfluenced by the patient's will, there are few curative remedies so important as the electro-magnetic current. I have seen a young woman, the subject of hysterical paraplegia for months, move the limbs, and walk, although unsteadily, in an hour or two after the application of electricity; and very lately, another was in Guy's Hospital under my care with paralysis of the right arm, in which the same successful results occurred. In neither of these cases could I detect simulation, and not only was there no motive for it, but the interests and desires of the patients were opposed to it, for the paraplegic girl was prevented from becoming a wife by her paralysis, and the young woman with the palsied arm had an aged mother, to whom she appeared deeply attached, depending upon her exertions for her means of support.

In connexion with these cases I may now allude to the voicelessness we occasionally meet

with in cases of hysteria. This is often a troublesome symptom, difficult to relieve. In the majority of cases this does not disappear until the anæmia, if present, is cured, and the general health restored as completely as possible. Even then, however, the aphonia will frequently baffle us. In such cases I have been often gratified by the result of the application of electricity. Sometimes on seating the patient on an insulating chair, connecting her with the prime conductor of the electrical machine, and drawing sparks briskly from the region of the larynx, the voice has almost immediately returned. In one case, which had been peculiarly obstinate, passing a gentle current from the electro-magnetic machine through the larynx, and only for a few minutes, cured the patient.

There is yet another form of paralysis by no means unfrequent in practice, dependent upon, or at least connected with, general anæmia, and accompanying enervation, and in which the sole appreciable cause of the want of power in the palsied limb, is an exhausted state of the great nervous centres. Such a condition we see occasionally in women suddenly exhausted by flooding labor, or more gradually drained of vigor and power by the more insidious effects of over-lactation, and sometimes merely leucorrhœa. It is perfectly true that the judicious practitioner can successfully treat these cases, first by arresting the drain upon

the system, if such continues, and then by building up power by good food and hæmatic tonics, especially preparations of iron. But if the want of power in the limb has been at all chronic, the palsied state by no means necessarily disappears *pari passu* with the restoration of general health. Time, and often a very long time, becomes an element in the restoration of the limb to its due allegiance to the will. In such cases the cure may be very remarkably expedited by the stimulus of electricity. One of the first cases in which I adopted this addition to our treatment occurred many years ago in the person of a lady (since dead from phthisis) whom I saw with my friend Mr. Pretty, of the Mornington Road. This lady, always of weak power, had been completely exhausted by suckling her infant, and gradually and insidiously she lost power in the left arm. When I saw her, this had amounted to nearly complete loss of sensation and motion; the latter function being, however, most deficient. Under judicious management, her general health had been much restored, but her arm remained useless. Believing that there was no organic disease, and regarding the state of the limb as one merely of deficient power, I suggested the application of a current from the alternating electro-magnetic machine down the arm, one conductor being placed over the cervical spine, the other being placed in a basin

of warm water in which the left hand was immersed. The result was very satisfactory: almost after the first application some little power returned, and by the daily use of the current the patient recovered, in a few weeks, complete power over the limb.

We not unfrequently meet with cases of paralysis which can only be explained by a direct reference to exhaustion of the nervous power. It most generally makes its appearance only in the lower extremities, developing a very perfect paraplegia. This want of power involves alike motion and sensation, and is almost always the result of excessive fatigue, particularly when the person has been for a long time accustomed to sit with the spine bent, during the greater part of the twenty-four hours. I know of one case in which a very zealous physician actually became thus palsied, after assiduously devoting his time to the study of certain phenomena of the microscope, in doing which, he for hours together robbed himself of the much-needed rest at night, and spent them in leaning over the instrument. There is, however, another cause, unhappily too rife, of these cases; the miserable result of the utilitarian dogmata now so fashionable, which makes human labor a marketable commodity without any regard to health. I may perhaps startle some by announcing the act, that it has occurred to me repeatedly to wit-

ness more or less complete paralysis arising from this cause among a class of laborers of the most oppressed and most unprotected character. I refer to the needle-women of this metropolis, a class of girls and women, who, to earn enough of the wretched pittance they receive from the agents who employ them to procure them the commonest necessaries of life, are often compelled to work for fourteen, sixteen, eighteen, and sometimes even more hours out of the twenty-four. They toil on, indeed, at the needle, until the sight fails as they drop asleep; starting up, after snatching a brief slumber, to resume their task. These poor creatures receive from three halfpence to fourpence halfpenny for making a shirt (for the latter sum indeed, producing such as are worn by respectable mechanics, and others of as high a rank in the social scale). They are often scarcely able to procure food, and are driven to intemperance too frequently to benumb the recollection of the wretchedness, or to prostitution to add to their miserable income. No wonder that they become exhausted, enervated, bloodless; and paraplegia is not unfrequently the result. Not long ago, I had under my care, in Guy's, a young woman who had once moved in a sphere of great respectability. She was quite paraplegic, and was so entirely destitute of all sensation that she was not conscious of anything, when a needle was inserted into one of her

feet. This poor creature had been exhausted by working in the way I have described, and she declared to me that, except by dozing in her chair, she had often not slept for two nights together. She had at first felt vague pains in her toes, then in her knees, rigidity came on, and ultimately she became as when I saw her; the lower half of her body being as powerless as if made of marble. In this, as in other cases of the kind, there was no evidence of organic lesion, and by due nourishment, rest in the recumbent position, and the use of iron and tonics, her general health was soon restored. The electro-magnetic current was then employed daily, and I had the pleasure of seeing this young woman in about three months walk out of the ward quite well. These cases are but little known, and will, we much fear, continue to occur, so long as the labor of the friendless and dependent female is regarded with no more feelings of sympathy or humanity than the amount of duty performed by a steam-engine, or any other machine.

In conclusion, I will trouble you with a few remarks, and they shall be very brief, in connexion with paralysis dependent upon *positive organic lesion of the cerebral or spinal centres.* My experience in these affections, so far as their treatment by electricity is concerned, has been large;

and without troubling you with details, the results may be stated in a few words:—

1st. When the lesion is recent, the cause producing the paralysis still active, electricity and its modifications not only do no good, but often do much mischief. I would give an especial caution where rigid arteries are known to exist, or ramollissement of brain suspected. In more than one example of these affections I have known a fatal apoplectic fit quickly follow the use of the remedy in question.

2dly. In paralysis accompanied by rigid flexure of the thumb or fingers, I have never seen electricity do any good.

3dly. In cases of paralysis depending upon some physical cause, as effusion or pressure from other sources, when the original cause has been removed by time or treatment, or both, the palsy remaining; electricity, and especially the electro-magnetic form of it, is of the utmost value. These cases are certainly not uncommon, and to them the old adage of "sublata causa, tollitir effectus," does not by any means apply. A patient has, for example, congestion, influencing chiefly one side of the brain; the arm or leg, or both, become paralysed. After some time the circulation is equalized, the pressure is removed, and the paralysis, if the case be recent, disappears. If, however, the congestion has been of longer duration, the palsy does not disappear

with the removal of the exciting causes, and then the passage of the single electro-magnetic current in the course of the nervous ramifications becomes invaluable. Often in a few days the patient recovers his power. In such cases of chronic paralysis, let me beg of you not to give up the electrical treatment too soon. Remember, that if the paralysis be long continued, some of the new tissue deposited in the palsied muscles, in accordance with the recognised laws of nutrition, has never contracted or moved under the influence of the will, and a patient persistence in the electrical treatment will be necessary before the new fibres become roused into obedience to the *vis nervosa* propagated along the nerves by the volition of the patient.*

Paralysis of sensation is occasionally met with, and, so far as I have seen, the anæsthesia is generally confined to a single limb, or part of a limb, and has almost invariably resulted from some depressing cause exerting a local sedative influence. An interesting case of this kind has been recorded by Mr. Christoffer. A patient who suffered from leucorrhœal discharge, was directed to use the cold hip-bath every morning. No reaction appears to have followed its use, but a loss of sensation was experienced in the integuments of the

chilled thighs and loins. This disappeared in half-an-hour until after the twelfth bath, when the paralysis of sensation was complete from the toes to the hips. She could walk about, and had perfect power of reaction, but cutaneous sensation was absent. The temperature, moreover, was lower in the legs than the arms. Mr. Christoffer most judiciously applied the current from the electro-magnetic apparatus, from the sacrum to the feet; sensation was soon restored, and the patient completely recovered. Early in this year, a man was admitted into Guy's under my care (in Spare Ward), who had complete anæsthesia of the right arm. This patient (a most respectable poor man) had been reduced to great distress by a series of unhappy events, and to furnish food for his children deprived himself of it, and often passed an entire day without a meal. Become depressed and anæmic, he one day felt giddy and fell. He was brought to the hospital, and when I saw him he had complete loss of sensation in the right arm, motion being perfect. He could hold anything in the right hand, so long as his eyes were fixed upon it; but the moment he ceased to look at it, he generally allowed it to fall. I was quite unable to elicit any evidence of sensation by any test I could apply. Generous diet, with iron and quinia, soon restored his health, without, however, very much improving the loss of

sensation. I therefore directed the alternating electro-magnetic current to be passed from the cervical spine to the fingers of the right hand. At first, his hands felt the pain of the passing electricity; in a few days sensation returned, and he left the hospital completely well.

I have next to direct your attention to some other affections in which we have employed electricity as a therapeutical agent. It would occupy several lectures, were I merely to detail a portion of the clinical experience accumulated at Guy's Hospital during the last few years on the subject. My limited time will, however, only permit me to glance at its results in some few affections, in which it appeared to me of most prominent service—as in chorea, amenorrhœa, and some forms of paralysis.

Notes of 37 cases of chorea have been preserved: of these

37 cases, { 17 males, / 20 females. } { 9 above 16 years. / 26 under 16 " }

Of these, in 25 the movements were universal,
" 5 limited to the right side,
" 1 " left "
" 2 " both arms,
" 1 " right arm,
" 1 " left arm,
" 1 " sterno-cleido muscles,
" 1 " pterygoid muscles.

The causes of the chorea in
17 were traced to terror,
3 " amenorrhœa,
3 " intestinal irritation,
2 " intense cold,
1 " rheumatic fever.
1 " intense grief,
1 " congenital,
1 " mechanical injury,
4 " no apparent cause,
4 " complicated with epilepsy.

Of these, 30 were completely cured,
5 were relieved,
1 refused to continue treatment,
1 uncured. This was a man, 61 years old, where there was a suspicion of spinal mischief.

It is well known that chorea is an occasional sequence of acute rheumatism: indeed, one celebrated physician and pathologist has even suggested the probability of the existence of some connexion between chorea and pericardial disease—a too frequent result of rheumatism in youth. That there is some relation, however distant, between chorea and certain states of the heart, is rendered probable by the frequent co-existence of a mitral murmur with this disease. Cases of rheumatic chorea are generally obstinate, but still appear to yield readily to electricity.

H. W., aged 8, a thin, but healthy child whose general health had been good, stated, that about six weeks previously she was suddenly seized with great pain in her legs, of which she lost the use. Under medical treatment, the pain left the legs, and attacked the abdomen, and then the arms. The joints did not appear to have been much swollen or red. She recovered in a month, and almost immediately became the subject of chorea, and was admitted into Guy's Hospital on Nov. 2, 1837. Her existing symptoms were, continual involuntary jactitation of the legs and arms, with continual contortions of the muscles of the face. She complained of stiffness in the neck, and spoke with extreme difficulty. She took vinum ferri and sulphate of zinc for some time; but, getting no better, electricity was ordered on Dec. 2.

Dec. 8th.—The sparks had been taken daily from the spine. She now speaks and swallows without the slightest difficulty: the involuntary movements of the limbs are much diminished.

18th.—She left the hospital quite free from all trace of chorea. She remained well until June 20, 1838, when she was brought to the hospital, affected with chorea, confined now to the upper extremities. The electricity was again ordered, and she rapidly got well.

That chorea is often excited by intestinal irritation, is well known, and the possibility of curing

such a disease with purgatives is notorious. It will, however, sometimes happen, that although the exciting irritant is removed, the effects on the nervous system remain, and the chorea persists. In such cases electricity soon effects a cure.

W. J., aged 12, who stated his general health to be good, had been long subject to tape-worm; he had never had rheumatism, or suffered from fright. His present attack of chorea commenced ten months ago, and, although he had been under treatment nearly the whole time, has never been much relieved: he therefore applied at the hospital, and was admitted on Nov. 1. He took purgatives and sulphate of zinc for two months, when not being any better, he was sent to the electrical room on Jan. 6. At that time his symptoms were the following: — involuntary movements of almost every muscle, so that he had considerable difficulty in walking, and was quite unable to support himself on one leg; his arms were in constant motion, and he had so little control over his fingers that he could not retain anything in his grasp, even for an instant; the muscles of his throat were also in a constant state of involuntary motion, so that his articulation was imperfect, and his words frequently unintelligible; his head was constantly moving, being, with his neck, alternately thrust forward, and retracted in

a jerking manner. Sparks were ordered to be drawn from the spine on alternate days.

Jan. 9th.—Much improved. Involuntary movement of the legs and arms much less.

13th.—Rapidly convalescing.

Feb. 9th.—Presented well.

Where chorea exists in girls, as a result of the disturbance of nervous functions from amenorrhœa, anæmia, either not existing, or previously cured by iron, it is a good practice to transmit a few shocks through the uterus, in addition to the sparks from the spine. In this way the catamenia will be generally excited, and the rapidity of the cure increased.

E. R., aged 16, of previous good general health, menstruated, for the first time, three months ago. After the disappearance of the discharge, she became the subject of involuntary movements of the right arm and hand; these have increased in intensity up to the present time. She appeared at the electrical room in July, 1838: sparks were taken from the spine, and a few shocks passed through the pelvis. After the electricity had been applied five times, the catamenia occurred, and the chorea vanished. She continued well until September 19th, when, as the discharge had not appeared at its proper time, she again applied at the hospital. A few shocks through the pelvis excited the deficient functions, and she left quite well.

I have never seen any good effect to result, in cases of chorea, from the transmission of electric shocks along the affected limbs: on the contrary, in every instance, the involuntary movements have been increased, often to an alarming extent; and, if employed when the patient was convalescent, it has invariably aggravated every symptom, and often rendered the patient as ill as when first admitted under treatment. The following case is one of several in which shocks were employed in the hope of accelerating the cure, but with the opposite effect of increasing the malady:—

J. B., aged 18, a stout, muscular lad, admitted into Guy's Hospital, stated, that until the last two months his health had been excellent. His employment, as a toll-gate keeper, had necessarily exposed him to the vicissitudes of the weather, which have induced repeated catarrhal attacks: to one of these he attributes his present illness. The involuntary movements first made their appearance two months ago, and are confined to the right half of the body, the left side being unaffected; they were sufficiently severe to prevent his retaining anything in his grasp, and to interfere materially with his walking.

Oct. 7th.—Sparks from the spine daily.—No medicine.

12th.—Improving rapidly; involuntary move-

ments occur, but slight; he can readily keep his right arm extended for a minute or two.

23d.—Scarcely a trace of involuntary movement of the arm left; the leg still remains slightly affected. With a view of ascertaining whether the progress of the case towards convalescence would be accelerated, a few shocks were ordered to be passed along the leg and arm.

26th.—He has grown rapidly worse since the employment of the shocks, and is now almost as bad as on his admission into the hospital. Sparks were again ordered, with gradually increased doses of sulphate of zinc, and in six weeks he was discharged, cured.

Electricity does not appear to be less useful as a remedial agent in cases in which the involuntary movements are confined to a single limb, or to a few muscles of the body only. It would be unnecessary to extend this paper by detailing other cases of ordinary chorea, particularly as they stand recorded in the Hospital Case-books: I shall therefore content myself with relating a few cases of the rarer forms of chorea, in which the disease is extremely limited in its seat.

S. W., aged 12, admitted into the hospital Nov. 5th, having been the subject of chorea during five weeks. The disease is confined to the right arm and shoulder, the limb being in a state of perpetual

movement. She attributes the attack to fear, produced by the threats of her schoolmistress. She took for some time sulphate of zinc and sesquioxide of iron, and then attended at the electrical room. Sparks were taken from the spine three times with considerable benefit, when she left the hospital. On the 20th of December she appeared at Guy's, among the out-patients, and came under my care. The involuntary movements of the limb were as bad as at first. Some saline rhubarb powder was ordered as an occasional aperient, and sparks drawn from the spine thrice a week.

Jan. 14th.—She has attended regularly, daily improving, and was to-day discharged, quite well.

The following curious case, although scarcely possessing the characters of chorea, is sufficiently marked to allow it to be regarded as a case of that disease: it still points out, in an interesting manner, the influence which electricity exerts over the involuntary movements of muscles supplied by spinal nerves.

J. T., aged 40, accidentally dislocated his jaw in the winter of 1838; and, after its reduction, became the subject, upon the slightest excitement, and often without any apparent cause, of involuntary motions of the jaw, apparently referable to the pterygoid and the depressor muscles: these produced dislocation of the jaw, often several times in the day. On October 9th, 1840, this patient ap-

plied at Guy's Hospital, and was sent to the electrical room. Sparks were drawn from the region of the affected muscles with remarkable effect, the involuntary movements diminishing so considerably that dislocation of the jaw rarely occurred. On leaving off the electricity, the motions returned, and with them the spontaneous dislocation; but whenever he recommenced its use, both these disagreeable symptoms vanished.

In another very remarkable case electricity was equally successful. The subject of it was a commercial traveller, who had been overtaken by a snow-storm on Salisbury Plain, and was nearly frozen to death. Soon afterwards, a curious form of partial chorea, affecting chiefly the sterno-mastoid muscles, appeared, and continued for a long time, the head being alternately carried by a series of jactitations from side to side with considerable violence, and he was accustomed to steady his head by holding his nose firmly with one hand. This man was long under treatment at the hospital, and ultimately recovered, on submitting him to the electrical treatment.

The results of my trials of electricity in chorea may thus be deemed very satisfactory. I am quite aware others have not met with the same success, and this is easily accounted for, in their merely seeking the aid of the remedy in cases which obstinately resisted all other means, instead of

using it as the primary remedy. Of all remedies I have hitherto used, except perhaps the sulphate of zinc, electricity seems most successful in chorea, and I have invariably employed it wherever I possibly could, since I first saw it employed by my friend and colleague Dr. Addison, who, I believe, first suggested its use in this disease.

More extended experience since the first publication of these cases in Guy's Hospital Reports, has more fully confirmed me in my confidence in this remedy. It has occurred to me many times during the past four years to suggest its use in cases occurring in private practice, which had run the gauntlet of all kinds of treatment in vain, and in several with the most satisfactory results. I confess I cannot account for the failure of electricity in the hands of others, although it may probably be explained by the mode of application. The cases under treatment at the hospital were watched by our pupils, and they stand recorded in the clinical report book of the ward, so that I presume the evidence in support of my statement may be regarded as sufficiently satisfactory.

It might now be inquired, in what manner does electricity cure chorea? Having reflected much on this subject, I have adopted the conclusion that, as a counter-irritant over the spine, it is more valuable than other remedies of this class, from its ready application, the intensity of its action, and

the capability of renewing it daily. It exerts a very important influence over the spinal nerves, and thus aids in submitting them to the influence of the will. In addition to this, I believe the remedy acts by exciting powerful contraction of the muscles, and thus aids in overpowering their irritability. Indeed, in this way, even independently of all counter irritation, I have more than once seen electricity cure chorea. A remarkable instance of this is at this moment in Guy's. A girl, æt. 14, was admitted under my care, in Miriam Ward, with obstinate universal chorea. I never met with a case in which there was no reason to suspect organic mischief, and which so completely resisted all remedies, the chorea movements continuing long after the restoration of her general health. I therefore left off all treatment, and requested my clinical clerk to pass a series of electro-magnetic currents through the arms. In a few days the movements lessened, and in a few weeks quite ceased.

Electricity has been repeatedly looked to as an important agent in stimulating the activity of secreting organs. We have evidence of its quickening the capillary circulation of the skin, and inducing perspiration, of which any one whose skin is not absolutely harsh and imperspirable may convince himself, by sitting on an insulated chair, and connect himself with the prime conductor of an electric ma-

chine in action, for ten minutes. This will seldom fail to induce free diaphoresis. I am by no means satisfied that the kidneys are excited to more active secretion by passing electric currents through them, or at least near them; but, in the case of the liver, I can hardly divest myself of the idea that I have seen a cholagogue effect produced by passing the shocks of an electric jar, or the electro-magnetic current, through that organ. I wish on this question, however, to speak with extreme caution. We have, however, most indisputable proof of the successful application of the stimulus of electricity in inducing secretion from the uterus in cases of amenorrhœa. In the clinical books we have abundance of such cases noted down. Whilst the electrical room at Guy's was under my charge, we had twenty-four cases of amenorrhœa reported; the youngest fifteen, the eldest twenty-five years of age, all unmarried.

Of these, 4 were chlorotic;
6 but slightly so;
12 not at all so;
2 complicated with hysteria.

Of these the remedy succeeded in all except the four chlorotic girls.

In electricity we possess the only really direct emmenagogue with which the experience of our profession has furnished us; I do not think I

have ever known it fail to excite menstruation where the uterus was capable of performing this function. Disappointment will, however, most certainly result if we have recourse to electricity merely because a girl does not menstruate; and we must never lose sight of the fact that, after all, the large majority of cases of amenorrhœa depend upon an anæmic condition; and the patient does not menstruate, simply because she has no blood to spare. Nothing can be more ridiculous than applying electricity or any other local stimulant to the uterus when chlorosis exists: the first great indication will be to restore general health, give iron to make up for the previous deficiency of that element in the blood, and then, and not before, think of stimulating the uterus. It is true that, in a large proportion of cases, the catamenia will appear as soon as the chlorosis is cured: of course, in such cases, there will be no need of the employment of electricity; but still a large number will occur in which, even after the complete relief of the chlorotic and anæmic condition, the uterus remains torpid and refuses to act. In such cases, a few shocks transmitted through the pelvis seldom, if ever, fail in effecting menstruation. I have repeatedly known the catamenia, although previously absent for months, appear almost immediately after the use of electricity; in more than one case the discharge actually appeared within a few

minutes. The mode in which electricity has been generally employed has been by transmitting a dozen shocks from an electric jar, holding about a pint, through the pelvis; one director being placed over the lumbo-sacral region, the other just above the pubes. In private practice, in which the employment of the cumbrous electric machine is very inconvenient, I have substituted with advantage the induced currents of the electro-magnetic apparatus, the conductors being placed as before. The alternating current from the common coil-machine may be employed in these cases, as the electricity seems to act simply as a local stimulant quite independently of the production of uterine contractions. Dr. Collins of Dublin seems to prefer the electro-magnetic current to the shocks of the ordinary electric jar. I believe it is a matter of complete indifference which we employ.

You will often find most satisfactory results follow the employment of electricity as a stimulant to the absorbents to quicken capillary action. Do not fancy, however, that you can absorb an ovarian dropsy or an ascites by these means. I have repeatedly and carefully tried the remedy in these cases, and without the slightest benefit. Still there are cases in which I have observed the most unquestionable evidence of its value. In chronic rheumatic effusion into the joints, providing it is

perfectly fluid and not too old, you will succeed in effecting its absorption by placing the patient in an insulated chair, connecting him with the prime conductor of an electrifying machine, and drawing strong sparks from the joints until the skin becomes red and papulated. There is at this moment under my care in the hospital, in Talbot Ward, a countryman, who came in after an attack of sub-acute rheumatism: the knee joints were distended with effusion, and he could hardly walk. By this treatment, independently of any other, the knees in three weeks became much reduced, and the man could walk with comparative comfort.

This treatment has also been recommended in strumous disease of the joints. In this I have had no experience, nor do I think I should be inclined to try the remedy in such cases.

You may often succeed in effecting a rapid resolution of acute inflammation of the tonsils, providing it be not too intense, by insulating the patient, and drawing sparks from the throat. This is an old remedy, and I can bear my testimony to its efficacy in some cases of this kind. In resolving inflammatory action, and in absorbing an effusion, I presume it is fair to explain the rationale of the influences of electricity less by any imaginary occult and peculiar power, than by a simple counter-irritant action, like that of a

blister, over which it has the great advantage of being often repeated without losing its influence on the part.

In the neuralgic pains so frequently accompanying muscular rheumatism in its chronic form, constituting, indeed, what is known by the public, *par excellence*, as "the rheumatic," I have often witnessed considerable relief by drawing sparks freely from the part until an urticarious eruption appears on the skin. A daily repetition of the remedy has often nearly completely freed the patient from his discomfort. An analogous plan has sometimes given great relief to a class of cases which are the plague of the physician—I mean the neuralgic pains of the side so frequent in hysteric and chlorotic girls,—pains which in former days, and indeed not very long ago, were too frequently regarded as depending upon pleurisy, to the destruction of the patient's health.

There is yet another application of electricity as a direct stimulant which it has occurred to me to witness. You are all aware that in cases of poisoning by opium, after getting rid of as much of the poison as possible from the stomach the great peril besetting the patient is the fatal indulgence of sleep. Every ingenuity has been often used to keep these patients awake until the narcoterin has passed off. In addition to the ordinary plan of dragging them about, flagellation has often been

resorted to: I have even seen the bastinado employed, by slapping the soles of the feet with a wet towel. Recently the painful stimulus of the alternating current of the electro-magnetic machine has been employed with marked success: Dr. Martin Barry was, I believe, one of the first who had recourse to this remedy in the case of an infant patient at the Edinburgh Maternity Hospital. The child, who was nine months old, was dosed to sleep with twenty-five minims of laudanum: it appeared, when Dr. Barry saw it, to be in a state of hopeless narcotism. By the application of the current from the electro-magnetic machine, the little patient was kept at least partially awake for nearly five hours, when the respiration became calmer, and the pupils dilated: the child eventually did well.

In the only case of poisoning by opium in the adult in which I directed the employment of the current, the conductors were placed in the moistened hands of the patient, and fastened to them by a piece of tape; the current thus passed without trouble, and with the very obvious result of arousing the patient.

I once applied this remedy to a very marked instance of that old disease Catalepsy. A young lady became the subject of this affection, and for hours together appeared perfectly ecstatic, the eyes looking upwards with a fixed gaze, and the body

assuming a rigid state, so that she resembled a statue. When left to herself she generally became fixed, in rather graceful positions than otherwise; but the limbs could be moved, like wax, in any position, and there they would remain. She remained once, to my own knowledge, for four hours in one position, and that an irksome one too. Finding all remedies fail, I had two basins of water placed on a table, each connected with a conductor of the double-current electro-magnetic machine. The next time she became cataleptic, her hands were immersed in these basins: in an instant the charm was broken, and she uttered a loud scream, nearly kicked over the table, burst into a flood of tears, and had no other attack. Real or assumed, the disease was cured.

I would strongly recommend a trial of the electro-magnetic current in cases of drowning. Here, when life has become apparently extinct, it would be worth trying how far the remedy might be of use. One of the conductors of the alternating machine might be applied to the neck, whilst the other is moved along the margins of the ribs from the scrobiculus cordis, so as to influence the diaphragm, and perhaps the ganglionic nerves. One case is recorded in which this remedy was successful in restoring animation. I am well aware that for the last fifty years a galvanic battery has always been included among the appli-

ances to be had recourse to in the treatment of drowning; but the trouble of getting it in action, as well as the experience required for its application, has placed it out of the reach of those who are generally called to such cases. These objections cannot apply to the electro-magnetic machines, which are made fit for use in a couple of minutes, and may be set to work by the least expert in these matters.

Much has often been said respecting the use of electricity in the treatment of amaurosis. I have seen it employed in the hospital under all forms of this disease, and regret that I have never been able to observe the slightest benefit in whatever way it has been employed. In deafness, also, it has been greatly lauded, but I have seen little which can bear out the commendations accorded to it by some writers. A great authority, Kramer, indeed, especially cautions us against the rash employment of electricity in deafness, regarding it as an excitant of the optic nerve, and likely to induce most unsatisfactory results. In some cases of partial deafness following quinsy, I fancy that good has occasionally resulted from drawing sparks from the throat and mastoid process. My experience in these cases is, however, too small to allow me to offer any authoritative opinion.

I have thus pointed out the results of some of our clinical experience in the application of elec-

tricity to medicine; and, had time permitted, I should have been happy to have done more, and alluded to other affections in which this remedy has been employed; but I dare not trespass further upon your kindness and forbearance.

But one duty now remains—that of taking my leave; and in bringing this, my prescribed task, to a conclusion, permit me to offer my thanks for the kind and patient attention with which these crude effusions have been received. Allow me, moreover, to offer an apology for the imperfect nature of many of the illustrations I have used, and to plead in excuse the harassing nature of the duties devolving upon me during the medical session. Permit me to assure you that I have deeply felt the responsibility attached to the high honor of addressing you in this theatre, and whatever may occur to me in the too often chequered path of professional life, I shall always look back upon having been called upon to deliver these lectures, as one of the highest honors that could have been conferred upon me by the College.

APPENDIX.

The following communications merit, I believe, a careful perusal: for the first I am indebted to the kindness of Mr. Spencer Wells, Surgeon, R. N. It contains a very interesting account of the results he had observed, both in his own practice and in the hospital at Corfu, from the application of the single pair of plates, and is remarkably corroborative of the observation I had myself made on the therapeutical influence of the single galvanic current in the wards of Guy's. The second communication is important, from the amount of experience it contains in connexion with the action of the electro-magnetic current on the uterus. Mr. Dempsey, whose acquaintance with the various branches of experimental philosophy is of no ordinary character, has entered into this inquiry with great zeal, and its results will, I think, be read with interest.

A.

24 Belgrave Square, July 16, 1849.

My dear Sir—

I have much pleasure in communicating, as you request, the results of observations made by myself since the paper I wrote in October, 1847, upon certain sanative effects of Galvanism. This paper was read before the Royal Medico-Chirurgical Society, Jan. 11, 1848, and published in the Medical Gazette, May 26, in the same year. It contained a short statement of the results of the application of a simple apparatus, consisting of an oval plate of zinc, from two to four inches in the long diameter, and of a plate of pure silver of the same size, the two being connected by a silver wire soldered to the back of each plate. I drew up the

statement, after carefully reading reports of upwards of forty cases furnished by students of the Civil Hospital at Corfu. The cases had been treated by a very able native surgeon, Dr. Cogevina.

I propose now to inform you how far the conclusions I then deduced from those cases have been modified by my own subsequent experience.

I have applied the same apparatus, and observed the effects in a great many cases of ulcer. I cannot say exactly how many, but I have notes of thirty-six; and I should imagine this is less than half the number treated. I also applied it in two cases of fistula, one perineal, the other vesico-vaginal: in four cases of fungous granulation, and five of nervous disorders. Many of these patients were under the care of Dr. McDonald and Dr. Millar, of H. M. S. Hibernia; and for the notes of most of them I am indebted to Mr. Duigan, Assistant-Surgeon, R. N. Others were under my own care in the Trafalgar and Locust while I was surgeon of those ships, and have formed the subject of official reports to the Director-General of the Medical Department of the Navy.

I will quote my former conclusions in order, and append to them the results of later observation.

"1. To secure the effects of the apparatus, it is necessary that the surfaces of the two metallic plates be perfectly smooth and clean, and that each be closely applied upon a part of the body denuded of cuticle. Thus when the effect upon one open surface is required, a small puncture must be made at some other part of the body to form the second."

After the word "clean" all this is incorrect. The plates must be applied to the body without intervention of any other substance; but denudation of cuticle is not necessary to secure the effects. They are as satisfactory if the zinc plate be moistened with vinegar, or an acid solution, as after removal of cuticle.

"2. Experience has proved that one of these surfaces must be superior, the other inferior, and that the plate of zinc must always be *above* that of silver."

I am sorry that I have not tried the effect of placing the zinc below the silver. I should probably have done so if I had ever found any difficulty in placing it above.

"3. When the plate of zinc is placed upon a slight excoriation, and that of silver upon a suppurating surface, the excoriation beneath the zinc plate is in two days converted into a superficial eschar an inch in circumference. In six days, the apparatus being still constantly applied, the eschar extends to the subcutaneous cellular tissue, and presents all the characters of a slough produced by caustic potash, except that the dead tissues are a little less compact. Cicatrization of the ulcers left after the separation of the sloughs being very tardy, it is necessary, in most of the therapeutic applications of the apparatus, to change the situation of the zinc plate every second day; and with this precaution no inconvenience results from the superficial sores."

The observations on the formation of eschars are quite true: but in practice it is better to avoid their formation altogether by substituting acid for puncture, unless it be desirable to produce the effect of moxa in this manner.

"4. When an ulcer presents an indolent or lardaceous base, this unhealthy base is destroyed, and the surface becomes a healthy granulating one, after three days' application upon it of the *zinc* plate. In this case the natural or artificial abrasion upon which the silver plate is applied must be inferior to that upon which the zinc is applied, or the good effects do not follow."

I have not found surfaces become healthy and granulating so long as the zinc plate remains applied upon them. On the contrary a dark, soft, spongy surface is produced and copious exudation of fetid serum. It generally requires two or three days after the zinc has been removed for this soft slough to clear away. I have not tried the effect of altering the relative position of the plates.

After the slough has separated, an excavation is left, and the granulations are healthy. They will reach the surface-level under any simple application, but they do so much more rapidly when the silver plate of the apparatus is employed. That this good effect is not due to mere pressure of the metallic plate, I have become convinced after comparative trials of the application of the silver with and without connexion with zinc. I have made numerous trials of the methods of Baynton and Scott, of water and dry dressings, of elastic bandages, and various other accepted

modes of treating ulcers, and have found no means so capable of uniformly producing a rapid growth of healthy granulation as galvanism. I have often been astonished at the change effected in twenty-four hours in the condition of ulcers. At one dressing they are seen to be deep, cup-like excavations; and at the next granulations have nearly reached the surface; and after another day the surface-level of the skin and granulations is uniform, the well-known marginal blue rim announcing the commencement of cicatrization. When this point is attained, it is better not to apply the apparatus again, but to employ simple water-dressing, or, if there be any tendency to flabbiness of the granulations, dry lint and a strap of adhesive plaster. During the few weeks I served in the Hibernia a form of contagious circular sloughing ulcer was very prevalent. We used to destroy the diseased surface by undiluted nitric acid, and as soon as the slough separated, apply the galvanic apparatus. The men often were allowed to walk about, and found no more impediment than from a simple bandage, and much trouble was spared in dressing. There is also a very obstinate form of ulcer naval surgeons are often called upon to treat, produced by ropes being by accident forcibly and rapidly twisted round the limbs of sailors during some nautical manœuvre. A ring of skin, cellular tissue, fascia, and sometimes of muscle, is thus destroyed as by a burn,—the sailors call it a "burn with a rope;" and when this ring completely surrounds a limb, the slowness of the natural process of repair is quite remarkable under any variety of ordinary treatment. I had a case of this kind in the Trafalgar. The skin and other tissues, with some portion of muscle, were destroyed all round the calf of the leg, laying bare both tibia and fibula. The slough separated, and an annular ulcer remained nearly two inches in breadth. The man was a long time on the sick-list before I thought of employing galvanism; and scarcely any signs of a reparative process had appeared. I then applied the silver plate of the apparatus to a portion of the ring, and it was quite extraordinary to trace the daily effects as the plate was moved around the large ulcerated surface, the spots where the metal had been applied for only twenty-four hours being kept above the level of other parts, and

consisting of small conical granulations in place of the "beef-steak" surface which had formerly existed. Cicatrization afterwards took place as readily as in ordinary cases.

"5. The zinc plate applied in the same manner upon flabby exuberant granulations or fungous growths, rapidly destroys them."

It does so, but less rapidly than nitric acid, nitrate of silver, or the chloride of zinc. I shall not employ it again for this purpose, as the pain is much greater, and for a longer period, than when ordinary caustics are used. The slough formed is also less firm, and does not separate so readily.

"6. When the silver plate is applied to a surface simply denuded of skin, the zinc being placed superiorly upon another such surface, even although the former be freely suppurating, it is very rapidly dried, and covered with a dense pellicle."

Quite true, although the zinc be simply placed in cuticle moistened with acid.

"7. When the two plates are similarly applied, the surface beneath the silver being a deep ulcer, rapid and healthy granulation follows. If the silver plate be left upon the granulating surface after this has reached the level of the surrounding integuments, the granulations become exuberant and flabby, sometimes fungous. In practice, therefore, the apparatus should be removed as the granulations reach the surface; and when this is done, spontaneous cicatrization follows."

Perfectly correct. Refer to remarks upon the 4th paragraph.

"8. When the silver plate is applied upon the superior portion of a very large ulcer, this portion only improves in appearance, while the inferior portion degenerates; but if the plate be applied upon the lower portion only, the whole surface of the ulcer improves equally."

This I have only tried once. The result quite accorded with the above statement.

"9. In cases where several ulcers exist upon a limb, and the zinc is applied to a superior, and the silver to an inferior one, or to denuded surfaces, all the ulcers situated in a direct line between the two plates improve in appearance, become healthy

sores, and cicatrize, while those on either side of the current remain unaltered, and sometimes degenerate."

In two cases in which I repeated this experiment the result agreed with that just stated.

"10. When the silver plate is applied upon the extremity of a fistulous sore, but little effect is produced; while, if a projecting portion of the silver be carried to the bottom of the fistula, granulation rapidly follows. To fulfil this object, Dr. Cogevina has silver plates perforated by screws of the same metal, the points of which are adapted to the shape of the fistula, and readily projected more or less by a simple turn of the screw. The application in these cases need not be more than a few days; for, as soon as healthy granulation commences, the apparatus may be removed, and cicatrization rapidly succeeds."

I found this answer perfectly in a case of perineal fistula, which persisted long after perfect dilatation of a stricture of the membranous portion of the urethra. In a case of small, deep-seated, vesico-vaginal fistula, the patient being nervous, afraid of chloroform, and in a state of general health which rendered confinement to bed objectionable, I employed a plan of treatment which I had successfully adopted on the recommendation of Dieffenbach in a case of a circular opening in the soft palate. The edges of the opening were touched with a camel-hair pencil which had been moistened in a strong tincture of cantharides. A vesicle formed, the epithelium was removed, and more or less contraction followed cicatrisation. This process was repeated until perfect closure ensued. I thought it might be hastened by applying the galvanic apparatus at night, and renewing it in the morning, attaching the zinc to the loins by a bandage. I can only say that it was not found difficult to insure proper adaptation, and that no harm was done, but probably some good, by preventing dribbling of urine into the vagina for some hours daily.

"11. In several cases normal innervation has been restored in paralysed parts under the use of this apparatus, the zinc being placed superiorly, and the silver inferiorly, so as to include, as nearly as possible, the whole of the paralysed part. Disordered

function of particular nerves has been also remedied by so placing the two plates that the nerve lies between them.

I have applied the apparatus in three cases of paraplegia in children. In two of these cases hemiplegia had been formerly suffered from; but the arm had recovered power, one thigh and leg remaining powerless. In the third case, the extensors of the thigh and leg were alone affected. I had the silver plate applied to the foot and the zinc to the spine, and left for several weeks. In the first two cases no benefit whatever has resulted. The third I have not seen again, although he has worn the apparatus about four months; but the mother writes that the limb is "certainly stronger, and gaining strength." I am doubtful, however, how far this can be attributed to the influence of galvanism, as the boy left off mechanical supports, which were doubtless injurious, and his general health has greatly improved. At any rate no harm has been done, and the mind of the mother has been satisfied: whereas if nothing had been attempted she would probably have tried some less harmless mode of treatment. I should say, that this boy had been for several weeks under the care of a professed "galvanic doctor," who had employed powerful shocks, and an apparently judicious system of friction without good effect, and with much suffering to the child, who was frightened by the shocks of the battery.

In two cases of nervous deafness I have had small plugs of the two metals made to fit the auditory canal, and lay upon the membrana tympani, the connecting wire crossing the head. Both patients complained of curious creeping sensations, and at times of pain in the head. One says he often hears a kind of low rumbling sound like distant thunder, and fancies his hearing is improving. In the other case no benefit has been derived. I tell them to wash the ears with tepid water twice daily after removing the apparatus, then to moisten the metals in a solution of common salt and reapply them. After wearing them thus for a few days they leave them off for a time to discover if any effect has been produced. Both are proceeding with the treatment at their own desire, rather than from any very sanguine expectation of success

on my part. No harm is done, and cleanliness is insured, while hope acts beneficially on their general condition.

"12. The action of the zinc plate is an excellent substitute for the common moxa, and for the caustic potass when obliteration of a vein is desired. In some cases of varicose ulcer, while the silver plate has been used to hasten cicatrization, an eschar has been purposely formed by the zinc over the dilated vein above in order to obtain a radical cure; and these objects have been readily effected."

I have not repeated this experiment because I believe the application of caustics to veins to be improper. I have twice seen fatal phlebitis induced by caustic potass under the direction of a most able and careful surgeon, who had repeatedly employed the same means before with success.

I still believe, as I formerly stated, that the means I had made known constitute "the best *general* method of applying electricity in the treatment of disease. The apparatus is cheap, simple, and portable; it operates without causing pain or uneasiness to the patient, nothing more than slight itching or numbness being felt: its action is, to a certain extent, regular and uniform, slow, and without violence; in all respects affording a much better imitation of the natural currents of vital electricity than the batteries in common use, as the action of the latter is powerful, and only susceptible of temporary application."

Before concluding, I may perhaps interest you by an account of some singular experiments I saw performed by M. Weylandt d'Hettanges, a French oculist of Dutch extraction. This gentleman passed a few weeks in Malta in the summer of 1847, and as he issued handbills stating that he was oculist to the Queen of Spain, member of several learned academies, and author of numerous works on the eye, patients flocked to consult him; especially as he stated that he gave advice gratis, being paid by the Duke of Bourdeaux to accomplish a mission of charity. As I was more anxious to obtain information, than scrupulous as to the source from whence I derived it, I attended frequently at the rooms of M. Weylandt, and thus saw a number of curious things I might

never have seen otherwise. Among others, he had a practice of passing long needles through the sclerotic and vitreous humor to the optic nerve in cases of amaurosis. He passed one needle into each eye, and then applied to the needles the wires of a galvanic battery of thirty plates. He thus passed several powerful shocks at intervals of a few seconds from one optic nerve to the other, through the brain, as he said. This he repeated twice a week, and, strange to say, very little ophthalmia followed such extraordinary proceeding. In one case his needle touched the edge of the lens, and the instant the galvanic circle was completed the lens became opaque. A cataract was instantaneously produced. This, at any rate, shows how powerful the current must have been. The application appeared to cause most intense suffering; indeed, I never saw such signs of intense agony as some of the patients showed. M. Weylandt assured me that he had employed this method in a "vast number of cases," and that his average success was one in seven. In ten cases in which I saw him employ it not the least good was done. At the time of the application some of the patients saw sparks of light, or flashes as of lightning, which M. Weylandt announced to be infallible precursors of success, but the event proved the contrary. After he left the island, at the desire of two of the patients, I continued the experiment, but in a rather different manner. I varnished two fine silver probes all over, except at the extremities, made a small puncture in the conjunctiva, and passed the probes along the course of the external recti to the optic nerve. Then I applied the poles of the battery, and repeated the application several times, but without success.

M. Weylandt also employed the same means in several cases of nervous deafness. He passed probes to the membrana tympani on each side, and then completed the circle of his battery. In other cases he put a silver catheter into the Eustachian tube on one side, and applied a probe to the membrana tympani on the same side, then by his battery, sent a shock through the internal ear. He always used a powerful battery, and repeated the application every second day. I did not see any good effect from it in one single instance.

I must now conclude a letter which, I fear, is far too long, and with many thanks for the information I have derived from your published lectures on electricity and galvanism, remain,

My dear Sir,

Very faithfully yours,

T. Spencer Wells.

Dr. Golding Bird.

B.

9 Wilderness Row, July 23, 1849.

My dear Sir—

I send you a classified abstract from my notes, of twenty cases in which I have used the electro-magnetic current from the ordinary coil machines. Of these twenty cases there were—

Uterine hemorrhage,		7
Ante-placental,	3	
Post-placental,	4	
Chorea with amenorrhœa,		3
Amenorrhœa,		5
Lingering labor, atony of uterus,		1
Hemorrhage at third month of pregnancy, with placenta previa, without uterine contraction, no pains,		1
Induced labor at seven months for pelvic malformation,		1
Passive menorrhagia, with fibrous tumor of os and cervix,		2
		20

Case 1st.—Mrs. M., Wakefield Street, Regent Square, æt. 32. Fourth child, labor regular, 12 hours; male child, born 10

minutes past six A. M. Hemorrhage set in immediately afterwards. All the usual means of inducing uterine action were tried in vain; ergot, cold friction; lastly, introduction of the hand into the uterus. Placenta found partially detached; the remainder was separated, hoping to procure contraction, aided by the irritation of the hand and fingers, but to no purpose. The patient had now lost a considerable amount of blood. I determined to use electricity. My machine was procured from the Royal Free Hospital close by. One electrode applied to the sacrum, the other to the os uteri through a glass speculum; after moving the electrode, previously applied to the sacrum, round the abdominal parietes for five minutes, energetic contractions ensued, expelling both placenta and a large quantity of coagulum. In a minute or two the uterus was felt firmly contracted, and all danger at an end. Some tenderness remained for a day or two, but the patient became quickly convalescent.

CASE 2d.—Mrs. J., Goswell Road, æt. 21. First child, labor set in at 4 A. M., with slight pains; from this period until 10 A. M. there has been profuse hemorrhage with every pain, latterly the patient has become much exhausted; has had no pain for forty-five minutes. Auscultation indicated no fœtal pulsation. Examination. Os uteri was found soft, yielding, dilated to the size of a crown; protruding through it was a portion of placenta; on detaching the placenta around the os and cervix, and pushing it to one side, the head of a full-grown fœtus was discovered presenting. I applied the electric current as above described; in seven minutes contractions came on. I now waited ten minutes; no indication of pain. Again applied the electrodes; again pains are induced, longer and more intense than the previous one; ten minutes, again, still longer pain; five minutes, again, and so on for forty-five minutes, at the end of which time the head pressed on the perineum; in five minutes the fœtus was expelled. It had also to be applied here to produce expulsion of the placenta.

CASE 3d.—Was almost identical with last described.

CASES 4, 5, 6, 7.—In these four cases of post-placental hemorrhage, the loss ceased almost immediately on passing the current through the uterus.

Cases 8, 9, 10.—In the three cases of chorea, two had been for some time taking ferrugineous preparations; one, Sulph. Zinci. Catamenia appeared in two, after three and five applications respectively. One was completely cured, the other much benefited; the third obtained no benefit; indeed the symptoms appeared aggravated after each application. She did not menstruate when last heard of.

Cases 11, 12, 13, 14, 15.—In the five cases of amenorrhœa, three were chlorotic, one plethoric, one apparently in general good health. Electro-magnetic currents were applied in the three first-mentioned cases after the anæmic condition had been removed. In the fourth, after the application of six leeches to the perineum. In the fifth, without any previous treatment. In every case the patient had directions to use a hip bath, containing bruised horse-radish at, bed-time, after the current had been applied. Menstruation occurred in each in the following order:—

Chlorotic patients, after 3, 5, and 8 applications respectively.

In the fourth, on first application before she had time to have the bath as directed.

In the fifth, in three applications.

In these five cases a gentle current was kept up for half an hour on alternate evenings.

Case 16th.—Lingering labor, with atony of uterus.

In this case labor was protracted for nearly thirty hours; pelvis capacious and well formed. Uterine action extremely feeble, with long intervals. When first seen the patient had been fainting for two hours, within short periods; on inquiry I ascertained there had been no pains for nearly three hours. Examination. Os quite obliterated, perfectly well-formed pelvis. Fœtal heart audible. Electro-magnetic current applied in the usual manner; on first application, patient complains of slight bearing-down pain. In five minutes applied again; now the pain is decided and energetic. After forty minutes the fœtus is expelled, alive and strong, the current having been passed every five minutes. In this case ergot had been administered freely previous to my having seen the patient.

Convalesced favorably.

Case 17th.—Hemorrhage in miscarriage without uterine action.

Mrs. H., Prospect Place, Holloway, has had passive hemorrhage to a very considerable amount during three days, caused by one of her carriage horses becoming restive whilst driving in the neighborhood of Highgate. I was requested to see her at 11 o'clock P. M.; find she had arrived at the third month of pregnancy. Examination. Os uteri rigid and unyielding, no pain whatever, nor has there been any; a portion of placenta can be felt protruding. There is a constant drain. Ordered Acet. Plumb. Copio, cold applications, to take small portions of ice frequently. Six A. M. loss still the same. Take five-grain doses of gallic acid every three hours. Two o'clock P. M., no abatement. Take ergot every twenty minutes for one hour. No improvement.

It now became seriously important to check the loss by some means. I therefore sent for an apparatus, and applied the current as usual. In sixty-eight minutes the fœtus, &c., was expelled; pain was not perceptibly induced for twenty-eight minutes. Contraction then came on forcibly and quickly.

Convalescent quickly.

Note.—This I consider one of the most instructive cases I have seen, as tending to establish the fact of the power of electricity inducing uterine contraction *de novo*, where the organ is *predisposed* to such action, and again of the vast benefit such agency will be to us in practice.

Case 18th.—Mrs. H., Skinner Street.

Had been attended by me in March, 1847, in conjunction with an eminent obstetric physician, when craniotomy was found necessary from pelvic malformation, and accordingly performed.

About twelve months afterwards I was engaged to attend the same lady, then in her fifth month of pregnancy.

Having a great objection to craniotomy, for many reasons not necessary to enter into here, I advised premature labor to be induced at the seventh month. Accordingly at this period I punctured the membranes, waiting forty-eight hours to see what effect this would produce. At the end of this time no appearance whatever of labor.

The apparatus was then used thus :—

For five minutes a gentle current was passed as described before : no effect; ten minutes elapse. Current passed again for five minutes, still no effect; another ten minutes interval. A third application for five minutes. Patient now complains of a slight grinding pain, quickly passing off. I now determined to wait half an hour to ascertain what effect the impetus given to the uterus would produce in keeping up its action. No pain or contraction ensued. For forty minutes the current was regularly transmitted for five minutes, at intervals of ten minutes; the pains now became steady and regular. On this being accomplished the action of the machine was discontinued. I sat by this patient eight hours, regularly noting by my watch each pain and its duration. The pains regularly recurred within twenty seconds of the ten minutes, lasting for twenty-five seconds, until the head rested on the perineum, then eight minutes, six, four, two, one, and half a minute, the last expelling the head. I was particularly anxious to have these periods accurately registered, having my assistant at the bedside to mark time as I called it.

This, and the previous case, to my mind sets the question at rest of the power of electro-magnetic currents to induce uterine contractions *de novo*, indeed, *a priori*, we could expect nothing else. If electric influence can produce contraction of fibres in one series of muscles, it would be only fair to infer that the same power will produce the same effect in a similarly organized structure.

The conclusions arrived at by me, from the opportunities I have had of observation in obstetrical practice are these :—

1stly. The current from an electro-magnetic apparatus can intensify already existing uterine action.

2dly. It is capable of inducing uterine action *de novo*, where the organ is *predisposed* to such action, either from congestion, a peculiar nervous condition, or the mechanical action of its contents.

3dly. That it is necessary to keep up the stimulus for a certain

period (imitating so far as possible nature's own efforts, by applications at regular intervals), to insure the permanent action of the uterine fibres.

4thly. That no injurious effect usually follows its application.

5thly. As an emmenagogue it is pre-eminently useful, after the anemic condition (if existing) be removed (the only time an emmenagogue can be useful).

6thly. I have frequently observed more certain effects produced by a current of considerable quantity, but of low intensity, as, for instance, by employing three or four batteries to the ordinary machine, regulating the intensity by the usual means.

With sentiments of great respect,

Truly, and sincerely yours,

JHN. DEMPSEY.

Dr. Golding Bird.

C.

Although exceedingly anxious to exclude from these pages anything of a controversial character, it is yet scarcely possible to avoid referring to some statements in connexion with the action of electric currents on paralysed muscles, which have led to a serious misunderstanding between two most distinguished physiologists. According to the views of one of these gentlemen, there is an augmented sensibility to the electric stimulus in the muscles of a palsied limb, providing the cause of the paralysis is strictly cerebral; the spinal marrow maintaining its connexion with the limb in complete integrity. This assumed exalted irritability is positively denied by the other physiologist.

I do not purpose saying one word respecting the hypothetical views advanced by either of these distinguished men, as this would be foreign to the subject of these lectures. It is merely in relation to their facts that I shall venture to offer a few remarks.

After a good deal of careful observation, and repetition of their observations, I am satisfied in my own mind of the truth of the following positions:—

1. Employing a current of electricity evolved by from three to twelve pairs of plates two inches square, excited by salt and water, taking care that the intensity of the current is only just sufficient to enable it to overcome the resistance opposed by the badly conducting structures it has to traverse, and never of sufficient intensity to produce pain. Connexion with the surface of the body being made through a piece of wet linen, the following effects were constant:—In cases of paralysis depending upon diseased brain, independently of spinal lesion, as in hemiplegia, with such a current, the muscles of the palsied limb are more susceptible to its influence than those of the sound one; slight twitchings being produced, when no motion whatever resulted when applied to a limb under the influence of volition.

2. Employing a current of electricity excited by a larger number of plates, and of a tension sufficient to produce a painful sensation in the sound limb, the muscles of the latter are always more obviously influenced than those of the paralysed side.

3. Employing the alternating currents of induced electricity evolved by any form of electro-magnetic machine, effects were always masked by the intensity of the agent, the pain and violent contractions produced effectually complicating and confusing the results.

I believe that both the physiologists alluded to, have described accurately all the phenomena which they observed, and the discrepant results at which they arrived are perfectly explicable on the very different conditions and intensity of the electric current they employed. To study the uncomplicated physiological effects of electricity on a muscle as a test of its irritability, the current employed should always be the feeblest possible, and applied according to the mode described by Marianini for obtaining what he calls the idiopathic shock (p. 97).

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THE END.